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OVERVIEW OF THE FRESH PACK FOOD INDUSTRIES

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The report reviews the pollution generated during the market proparation of fresh fruits, vegetables, fish and shell eggs. Ten of the largest volume crops of fruit and begetables are discussed. For each commodity the unit operations are described along with the extent of water usage and emission sources. For further information, contact the Food and Wood Products Branch of IERL-Ci.

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ABSTRACT

Pollution sources generated during the market preparation of fresh fruits, vegetables, fish and shell eggs were assessed. From the over one hundred different fruits and vegetables that are grown commercially in the United States, ten of the largest volume crops were selected for this study representing over 70 percent of the total volume. In addition, because of the specificity of their handling requirements, two nut crops, two species of fresh fish and fresh eggs were also included in this study. The method of approach used in conducting the study was to prepare descriptions on unit operations for each crop and to identify the extent of water usage, sources of effluent and emission from each step from harvest to shipment to market.

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SECTION 1

INTRODUCTION

The fresh produce industry is a major segment of the food industry in terms of volume marketed, number of establishments, and wash loads generated. All fruits and vegetables are processed to some extent before being displayed to consumers as fresh produce. Sometimes these operations are done in the field, such as curing (onions), trimming, or topping (lettuce, celery). Size-grading and packaging are usually done in packing sheds near the growing sites. However, several fruit and vegetable crops require more than these simple processing procedures. Some produce requires special treatment, such as air cooling or hydrocooling (lettuce), postharvest fumigation (grapes), or ripening treatment under a controlled atmosphere (lemons) to extend their shelf life. Others are treated with coating substances (oranges, apples, cantaloupes) and food coloring (oranges in Florida) to improve their visual appeal and shelf life and thus enhance their market value. In such instances, further processing is usually done in central plants whose sole function is fresh commodity production; occasionally it is done in conjunction with a canning and/or freezing operation.

Within this industry, no EPA studies have been conducted to describe the industry and the associated pollution problems. In this study we present data on the size of the industry and review the environmental problems associated with the market preparation of 15 selected important commodities. The ten selected fruit and vegetable commodities represent more than 70 percent of the total volume of that industry, based on 1975 government statistics. Walnut and almond represent 71.4 percent of the nut crops. In addition shell-eggs and two species of fresh fish were included in this study.

SECTION 2

SUMMARY AND CONCLUSIONS

Market preparation of most fresh fruits, vegetables, fish, and shell eggs requires substantial use of water and generates organic wastes. Although more than one hundred different fruits and vegetables are grown commercially in the United States, ten of the largest volume crops represent over 70 percent of the total volume. To assess the contribution of the fresh produce handling industry, to pollution problems, we have reviewed the common unit operations applied following harvest and the water usage and waste disposal associated with the ten highest volume crops. Because of the specificity of their handling requirements, we also included two nut crops, two species of fresh fish, and fresh eggs in this investigation.

From this analysis, we have made the following conclusions about the fresh produce handling industries:

- The industries are not a major source of air pollutants. Gaseous compounds such as ethylene, carbon dioxide are applied at low concentrations (0.1 and 1-8 percent level respectively), therefore they do not measurably change the air composition of the surrounding area. Sulphur dioxide used for grape fumigation is applied in enclosed storage area at a 2 percent concentration. Some operations are sources of unpleasant odors, but they create only local annoyance. Most of them, such as onion and garlic curing, are seasonal operations and are located some distance from densely populated areas. Malodors from egg-washing operations, however, can create a significant year-round problem and occasionally have elicited major complaints from nearby communities. Technology is available to contain and treat the contaminated egg wash water and to control emission of malodor.
- The industries are major sources of solid wastes comprising various natural organic substances. However, the quantity of such wastes is minor when compared to the entire solid wastes generated by the food processing industry. Large portions of these wastes are returned to the field, or used as by-products, fuel, or feed, and only minor portions are handled in central locations where they occasionally create local problems when disposed to city sewage systems. The sizeable wastes from nut shelling are eliminated because they are used completely as fuel or other by-products.

- The industries are major users of water, because the market demands clean produce. Most water is used to clean fresh produce, and therefore will be contaminated with soil and plant residues. Besides washing, cleaning water is used for transporting fruits through grading and inspection systems (hydro-handling), and for cooling fresh fish, fruits and vegetables (iceing, hydrocooling).

- The industries are creating large volumes of wastewater with varying strengths of organic pollutants. Fresh market preparation of onion, garlic, grapes and lettuce does not require water use; nuts, melons and celery preparation necessitates only insignificant use of water, for occasional washing and hydrocooling. However, water is used in significant quantities for the fresh market preparation of apple, citrus fruits, potatoes and eggs. Data collected in this study indicates the following water usage for these produce: apples 10,000 gallon/day (38,230 l/day) for 10,000-20,000 cartons/day production (36 to 44 lbs or 16.3-20.0 kg each); oranges 850-1050 gallon/hours (3,217-3,974 liter/hour) producing 1,000-1,200 field boxes/hour (50-55 lbs (22.7-25 kg. each); lemon 935-1,235 gallon per hour (3,539-4,674 liter/hour) producing 1,000-1,200 field boxes/hour (40 lbs or 18.2 kg each); potatoes 4.58-10 gallons (17.3-37.9 liters) per hundred weight (45.4 kg).

  Based on these figures water usage was calculated for the preparation of 1 million pound (4,540 kg) produce and the annual water usage for each crop was projected (Table 1). Assuming that waste water is equal to water intake the total waste generated by the four largest water user crop is less than 2 percent of the waste water flow volume of the canned and preserved fruit and vegetable industry, which has been previously estimated at 130 billion gallons per year.

  No information was obtained to indicate that hazardous pollutants are present in wastes discharged from fresh produce handling facilities.

  The wastewater contains some detergent compounds which are applied in the cleaning processes. Cleaning water and hydrocooling water is also frequently treated with germicides, and therefore these compounds enter into the waste streams. Chlorine at concentrations between 2 and 20 ppm is used most frequently as a germicide. Other compounds primarily applied to the water in citrus fruit operations include Sodium-o-phenylphenate (SOPP) at 2-3 ppm level, 1% 2-aminobutene, methyl bromide, ethylene dibromide and benzimidazole. Surface coating, coloring (Florida oranges only) and sprout inhibition (potatoes) compounds are applied after the last washing and therefore they do not contaminate the waste water. The only exception to this is the removal of lemon storage waxing compound by washing.

TABLE 1. ESTIMATED ANNUAL WATER REQUIREMENT FOR THE FRESH MARKET PREPARATION OF SELECTED FRUITS AND VEGETABLES
(Major crops with high water requirements were selected)

Crop	Water requirement for preparation of 1 million pound (4,540 kkg)		Estimated yearly production in U.S.		Estimated water use in U.S.	
	Gallon	Cubic meter	Million pound	Million kkg	Million gallon	Thousand cubic meter
Apple	6,300-25,000	24-97	3,865	17.5	24-98	92-369
Orange	18,600-23,000	71-87	3,900	17.7	73-90	275-340
Lemon	23,400-30,900	89-117	839	3.8	20-26	74-98
Potato	45,800-100,000	173-378	15,900	72.2	730-1590	2760-6020

- The wastewater is often disposed on land in the field. Central packing houses however, frequently discharge to municipal treatment plants. Very little information was obtained on the effluent quality in terms of COD, BOD, or suspended solids. Some of the values that were obtained are listed below:

Sunkist orange packing plant (Ontario, California)	COD of effluent from 3420-3760 mg/l (discharged into city sewer)
Norco Ranch* (Riverside, California) *(One of the largest US egg processors with a wastewater discharge volume of 30,000 gal/day (113,400 l/d)	BOD of effluent 2850-4000 mg/l (discharged to a land application system)

- The industries are not introducing harmful chemicals from disposal of material containing pesticide residues or other potentially hazardous chemicals. All chemicals applied by this industry are carefully screened before their use is legally permitted. Generally, those substances are used at very low concentrations that are not likely to create harmful effects to the environment.

SECTION 3

BACKGROUND

The significance of the size of the fresh fruits, nuts and vegetables industry is recognized in that approximately 40 percent of the total fruit and 46 percent of the total vegetables are consumed in fresh form.

This study undertaken by SRI International covered 12 commodities in this industry, representing approximately 70 percent of total fresh fruit, nut and vegetable consumption in the United States. These commodities were:

- Vegetables:
  - Potatoes, approximately 32.1% of total fresh vegetable consumption
  - Lettuce, approximately 13.5% of total fresh vegetable consumption
  - Onions, approximately 7.1% of total fresh vegetable consumption
  - Celery, approximately 4.0% of total fresh vegetable consumption
  - Melons, approximately 10.9% of total fresh vegetable consumption

  Total: 67.6%
- Fruits:
  - Oranges, approximately 24.5% of total fresh fruit consumption
  - Grapefruit, approximately 12.9% of total fresh fruit consumption
  - Lemons, approximately 3.1% of total fresh fruit consumption
  - Grapes, approximately 3.8% of total fresh fruit consumption
  - Apples, approximately 27.4% of total fresh fruit consumption

  Total: 71.7%
- Nuts:
  - Walnuts, approximately 31.8% of the total nut crop
  - Almonds, approximately 39.6% of the total nut crop

  Total: 71.4%

In addition to the above, fresh eggs and two fresh fish species were covered by the study.

SECTION 4

METHOD OF APPROACH

In conducting this study, SRI International gathered data from three sources:

- A comprehensive literature review of government, trade association, and industry publications
- Personal interviews with university agricultural extension staff in Florida, Idaho, Washington, and California
- Field surveys among growers, packing shed operators, grower cooperatives, and trade associations in Florida, Washington, and California.

Relevant information gathered from these sources was collated with selected nonproprietary in-house data at the project team's disposal, and this information was used to compile a general description of each industry and the unit processing operations common to each.

COMMON UNIT OPERATIONS

Harvest, transport, storage, and marketing of fruits and vegetables are the common unit processing procedures requiring the skills and ingenuity of people in this industry. After vegetables reach harvest maturity, speedy operations are required by growers, handlers, marketing specialists, wholesalers, and retailers to move produce from the farm to the consumers. It is important to recognize that fruits after harvest continue to carry on most of the life processes that predominated just before harvest. They respire, and in doing so use up oxygen, give off carbon dioxide and ethylene, and generate heat. Moisture loss or transpiration are also continuous. Since moisture content of most fruit and vegetable is high, this weight loss during transport and storage can be a serious economic factor.

The principal factors that require attention during the handling of fresh fruits and vegetables are:

(1) Metabolic changes associated with respiration, ripening, and aging (composition, texture, color).

(2) Moisture loss, with resultant wilting and shriveling.

(3) Bruising and mechanical injury.

(4) Parasitic diseases.

(5) Physiological disorders.

(6) Freezing and chilling injury.

(7) Flavor changes.

(8) Growth (sprouting, rooting).

Important features of the environment that influence the longevity of the produce, and that are amenable to control, are temperature, humidity, and the composition of the atmosphere surrounding the produce. Low temperatures depress the physiological activity both of the vegetable tissues themselves and of any micro-organisms capable of causing spoilage. High humidities reduce loss of water from the tissues and therefore retard wilting or desiccation, but they may encourage the germination and growth of organisms on the surfaces. Increases in carbon dioxide concentration and reduction in oxygen concentration, whether arising naturally as a result of the respiratory activity of the products themselves or brought about by artificial means, both generally slow down the normal metabolic activity of the plant tissues and inhibit the growth of spoilage organisms. Finally, some physiologically active constituents of the volatile emanations from ripening fruit, notably ethylene, can initiate premature ripening and other unwanted changes in material exposed to the same storage atmosphere.

Precooling is the rapid cooling of a commodity after harvest, before it is stored or moved in transit, before or after packaging. The rapid removal of field heat is essential for preventing deterioration of the more perishable vegetables. The more quickly field heat is removed after harvest, the longer produce can be maintained in good marketable condition. Precooling slows natural deterioration, including aging and ripening; slows growth of decay organisms (and thereby the development of rot); and reduces wilting, since water losses occur much more slowly at low temperatures than at high temperatures. After cooling, produce should be refrigerated continuously at recommended temperatures. Types of precooling include hydrocooling, vacuum cooling, air cooling, and cooling with contact ice and top ice.

Hydrocooling is commonly used for vegetables such as asparagus, celery, sweet corn, radishes, carrots, and cantaloupes. Among fruit crops, peaches, processing cherries, and very few apples are hydrocooled; citrus fruits are hydrocooled to a limited extent in Florida but not in California or Texas. Hydrocooling water is recycled, and thus screens must be used in hydrocoolers to remove trash and sediment from the water. Hydrocoolers are an excellent source of contamination of fruit with decay organisms. The tanks should be cleaned and the water must be changed daily; the water must be treated with a fungicide to prevent build-up of spores during the day. Chlorine, sodium o-phenylphenate (SOPP), benomyl, and benlate are used in hydrocoolers to control microorganisms.

Vacuum cooling is used for leafy vegetables, that are difficult to cool by other methods. Field-packed products are cooled quickly and

uniformly in 20 to 30 minutes. Most lettuce is now vacuum-cooled before shipping. Some celery, cauliflower, sweet corn, carrots, and radishes are also vacuum-cooled.

Green beans and tomatoes are often air-precooled before loading and during transit. Grapes are precooled by air in special precooling rooms or by forced air. They are treated with SO_2 prior to precooling. Oranges are room-precooled in California. Use of contact ice and top ice is also effective in precooling. These methods entail the use of crushed or finely chopped ice, either placed within containers in direct contact with produce or on top of packed containers. Contact- and top-icing are widely used in shipping leafy vegetables, such as spinach. Top-icing is used in shipment of root crops, such as radishes and carrots, and some loads of celery and sweet corn. It is also used to precool shipments of cantaloupes packed in wooden crates.

The transport of fruit and vegetables from region of production to that of consumption can in modern circumstances involve considerable periods of time; thus, it is highly desirable, and indeed in many cases essential, to control the conditions during transit so as to reduce wastage. The International Institute of Refrigeration (IIR) has made recommendations (1963) with regard to the most suitable conditions for the land transport of perishable foodstuffs, and their recommended temperatures for a range of fresh fruit and vegetable products are reproduced in Table 2.

The ranges of temperature given in Table 2 are suggested as suitable during relatively short periods in transit (or storage) and are not necessarily those that will give the longest possible useful storage life for the products concerned. Further reductions in temperature, which are limited by the need to avoid chilling injury, will in many cases permit the maintenance of good quality during varying periods of subsequent storage.

Optimal temperature ranges for the long-term storage of various fruit and vegetable commodities are summarized in Table 3, which also includes for each material an estimate of the storage life to be expected under the specified conditions.

The humidity factor in storage also must be kept within desirable limits. High humidities increase the danger of microbiological spoilage, but are necessary in most cases to prevent the material from shriveling or wilting. Most fruits keep best at a relative humidity of about 90 percent. Some leafy vegetables such as lettuce, spinach, endive, broccoli, and celery are especially susceptible to wilting and are better stored at even higher humidities, while certain other products, notably onion, pumpkin, and sweet potato, maintain their quality for longer periods when kept in a relatively dry atmosphere. Recommended humidities for the storage of individual commodities are given in Table 3.

TABLE 2. RECOMMENDED TEMPERATURES FOR THE TRANSPORT AND SHORT-TERM STORAGE OF FRUIT AND VEGETABLE PRODUCTS (International Institute of Refrigeration)

Species	Conditions for 2-3 day transport or storage				Conditions for 5-6 day transport or storage			
	Maximum loading temperature		Recommended transport or storage temperature		Maximum loading temperature		Recommended transport or storage temperature	
	°F	°C	°F	°C	°F	°C	°F	°C
Apples	No recommendation		37-50	+3-+10	No recommendation		37-50	+3-+16
Citrus fruit								
Oranges	50	+10	36-50	+2-+10	50	+10	39-50	+4-+10
Mandarins	46	+8	36-46	+2-+8	46	+8	36-46	+2-+8
Lemons and grapefruit*	54-59*	+12-+15*	46-59*	+8-+15*	54-59*	+12-+15*	46-59*	+8-+15*
Grapes†	46	+8	32-46	0-+8	43	+6	32-43	0-+6
Lettuce	43	+6	32-43	0-+6	39	+4	32-39	0-+4
Melons*	46-50*	+8-+10*	39-50*	+4-+10*	46-50*	+8-+10*	39-50*	+4-+10*
Onions	68	+20	30-68	-1-+20	59	+15	30-59	-1 to +15
Potatoes	--	--	41-68	+5-+20	--	--	41-68	+5-+20

* Optimum temperatures depending on variety.

† Precautions must be taken to avoid condensation on the surfaces of these products.

TABLE 3. RECOMMENDED TEMPERATURE AND RELATIVE HUMIDITY, APPROXIMATE STORAGE LIFE, HIGHEST FREEZING POINT, WATER CONTENT, AND SPECIFIC HEAT OF FRESH FRUITS AND VEGETABLES IN COMMERCIAL STORAGE

Commodity	Temperature	Relative Humidity	Approximate Length of Storage Period	Highest Freezing Point	Water Content	Specific Heat
	°F	Percent		°F	Percent	Btu /lb./°F
Fruits						
Apples	30-40	90	3-8 months--------	29.3	84.1	0.87
Grapefruit California and Arizona	58-60	85-90	4-6 weeks---------	----	88.8	0.91
Grapefruit, Florida and Texas	50	85-90	4-6 weeks---------	30.0	88.8	0.91
Grapes, Vinifera	30-31	90-95	3-6 months--------	28.1	81.6	0.91
Grapes, American	31-32	85	2-8 weeks---------	29.7	81.9	0.86
Lemons		85-90	1-6 months--------	29.4	89.3	0.91
Limes	48-50	85-90	6-8 weeks---------	29.1	86.0	0.89
Oranges, California and Arizona	38-48	85-90	3-8 weeks---------	29.7	87.2	0.90
Oranges, Florida and Texas	32	85-90	8-12 weeks--------	30.6	87.2	0.90
Tangerines, Temple oranges and related citrus fruits	32-38	85-90	2-4 weeks---------	30.1	87.3	0.90
Vegetables						
Celery	32	90-95	2-3 months--------	31.1	93.7	0.95
Garlic, dry	32	65-70	6-7 months--------	30.5	61.3	0.69
Lettuce	32	95	2-3 weeks---------	31.7	94.8	0.96
Melons:						
Cantaloupe (3/4 slip)	36-40	85-90	15 days----------	29.9	92.0	0.94
Cantaloupe (full slip)	32-35	85-90	5-14 days---------	29.9	92.0	0.94
Casaba	45-50	85-90	4-6 weeks---------	30.1	92.7	0.94
Crenshaw	45-50	85-90	2 weeks----------	30.1	92.7	0.94
Honey Dew	45-50	85-90	3-4 weeks--------	30.3	92.6	0.94
Persian	45-50	85-90	2 weeks----------	30.5	92.7	0.94
Onions (dry) and onion sets	32	65-70	1-8 months--------	30.6	87.5	0.90
Onions, green	32	90-95	----------	30.4	89.4	0.91
Potatoes, early-crop		90		30.9	81.2	0.85
Potatoes, late-crop		90	----------	30.9	77.8	0.82

Source: J. M. Lutz and R. E. Hardenburg 1968. The commercial storage of fruits and vegetables, and florist and nursery stocks. USDA Agriculture Handbook No. 66.

Among various supplements to refrigeration, control atmosphere (CA) storage is the most widely used to control decay, ripening, and other deterioration. For some fresh produce, reducing the oxygen level in storage air and/or increasing the carbon dioxide level as a supplement to refrigeration can provide extended storage life.

CA storages hold an important and increasing part of the apple crop. About one-third of the stored apple is kept in CA storage. The advantages are: (1) storage life of apples can be prolonged beyond the normal life in regular cold storage, (2) some varieties subject to low temperature disorders can be held for a long period at higher temperature, (3) fruit removed from CA storage keeps longer than fruit held an equal time in regular storage, (4) it is rodent proof, (5) relative humidity can be maintained about 90 percent with little danger of mold growth, (6) apples from CA storage have more of a "fresh apple" taste.

The essential features of CA storage are:

(1) Use of mechanical refrigeration to maintain temperatures of 30-32°F or 36-38°F, depending on the variety stored

(2) The storage room is specially constructed to be gas-tight for regular CA storage or suitably tight for an externally generated atmosphere introduced into the room

(3) In regular CA storage, oxygen is reduced and carbon dioxide is increased by the respiring fruit. Nitrogen gas may be introduced into the storage by portable equipment to hasten the reduction of oxygen after the storage room is filled and sealed

(4) In regular CA storage, excess carbon dioxide is removed by water scrubbing, or supplemented by caustic soda when necessary, or carbon dioxide is absorbed by dry hydrated lime

(5) The oxygen level is usually held at about 3 percent and carbon dioxide at about 2 to 5 percent, depending on fruit variety. If oxygen is below 18 percent in a CA room, individuals entering the room must wear suitable air-supplying or oxygen masks. For loading or unloading of fruit, the atmosphere must be flushed out to raise oxygen up to at least 18°C and reduce carbon dioxide to a low level.

The use of modified atmospheres to supplement the benefits of refrigeration during transit is also increasing. A variety of systems offered by different companies provide controlled or modified atmospheres in trucks, piggyback trailers, and railcars. They all provide an alteration of the levels of oxygen, carbon dioxide, and nitrogen surrounding the produce.

At least four systems of modifying the atmosphere in transport vehicles are available commercially: (1) using liquid nitrogen as a

refrigerant; (2) mechanical refrigeration with liquid nitrogen as a supplement, used initially, and in transit for atmosphere modification; (3) mechanical or ice refrigeration with dry ice (carbon dioxide) as a supplement; (4) mechanical refrigeration with the load compartment purged with a desired atmosphere at shipping point and then sealed without further addition of the modified atmosphere. Low oxygen atmospheres are obtained by a combustion process that burns most of the oxygen from the air and leaves a higher concentration of nitrogen gas.

Currently, lettuce is the main vegetable shipped under a modified atmosphere. The physiological disorder known as "russet spotting" is reduced when lettuce is shipped in low oxygen atmospheres. However, lettuce is damaged by accumulated carbon dioxide; therefore, hydrated lime is placed in the cargo to absorb carbon dioxide.

Ethylene is one of the volatiles produced by most fruits and vegetables at a certain stage of development. It is a physiologically active compound, and when it reaches a high enough concentration, it triggers the ripening process. Ethylene has been used to ripen honeydew melons and tomatoes, and for degreening of citrus fruits. The control of ethylene concentration is often necessary because of its undesirable effects. It can induce premature ripening of fruits, defoliation of plants, bitterness in carrots, and russet spots on lettuce.

PREPARING FRESH PRODUCE FOR MARKET

Trimming

The appearance of vegetables may be improved by removing damaged, diseased, dead, or discolored parts. Some field trimming is desirable for most vegetables, but sufficient wrapper leaves are left on such crops as lettuce, cabbage, and celery for protection.

Field Packs

Berries for the fresh market, including grapes, are usually packed into shipping containers as picked. Physical damage to these tender fruits is reduced when they are handled only by the pickers. Similarly, lettuce and celery are field packed and shipped to the market without washing.

Washing

The market demands clean produce, so most fresh produce is washed after harvest, to remove dirt, freshen the produce and reduce spray residues. Most of the root crops, however, should not be washed until they are marketed. Musk melons, cucumbers, and sweet potatoes are usually cleaned by brushing or wiping dry, rather than by washing.

Dumping the Field Containers

The fresh produce is transported in lug boxes or bulk bins to the packaging line. Today, usually mechanical dumpers (hydrodumping) are used, which transfers (dumps) the fresh produce into water.

The flume water is usually chlorinated, and depending on the type of crop and its condition, detergent may also be used.

Fruits with encrusted dirt or insects, and fungus or spray residues or stains require more than soaking and rinsing. In these cases, many types of proprietary washing compounds and brush assemblies are applied, including foaming materials, detergents, and soaps, to improve the visual appeal of fresh produce and to reduce spore contamination on the fruit surface.

Today, insect and other plant diseases are controlled with fewer sprays of more effective and less stable chemicals than those used prior to 1945, which contained arsenic and lead. Thus, chemical residues are seldom present in hazardous amounts on any of the fruits or vegetables at harvest time. When visible residues of insecticides, fungicides, or calcium sprays are objectionable at harvest time, the brushing or washing commonly used for routine cleaning generally suffices. Sodium o-phenylphenate (SOPP) is a fungicide commonly used in the washing process for citrus fruits. When SOPP is used for the fresh fruit market, pH control is critical. If pH is allowed to drop, a severe burn of the fruit can occur. For this reason, pH is usually controlled in a range of about 11.5 to 11.8 with caustic soda. In this pH range, SOPP residues are kept around 2-3 ppm, well within the 10 ppm tolerance level set for fresh fruit.

The compound 2-aminobutane (butylamine) is also used sometimes in 1% aqueous solution in the flume water of citrus products. It does not accumulate in the oil cells, and, therefore, its residue can be kept below the 30 ppm tolerance level set for fresh citrus fruit.

Fumigation

Products

Certain production areas, states, or countries that are free from specific crop-infesting insects or diseases require that selected products be subjected to proven treatments for disinfestation, or be inspected and officially certified as free from the insect or disease in question.

The two fumigants in wide use are methyl bromide (MB) and ethylene dibromide (EDB). (Carbon disulfide and hydrocyamic acid are no longer in common use for this purpose.) Each must be used under carefully controlled conditions to ensure control of insects and to avoid injury

to the product being treated. EDB is recommended for citrus fruits, stone fruits, cucumbers, green beans, and zucchini squash shipped from Hawaii to the Mainland, whereas MB is commonly used for disinfestation of potatoes, sweet potatoes, and tomatoes, and under vacuum for garlic.

Benzimidazole fungicides (principally thiabendazole and benomyl) are the most widely used fungicides for citrus products.

Conditions of Use

Insect quarantine regulations can be met by fumigation with these approved materials in a rail car, highway van, fumigation chamber, and under tarpaulins. In each case, the facility must meet certain standards of construction and gas tightness. Temporary sealing materials, such as wide masking tape, are usually required at doors and vents in transport vehicles.

Tarpaulins must be of specified materials, and the floor under the tarps must be covered with plastic film or laminated asphalt-coated paper to prevent gas penetration; joints between the tarpaulin and the floor sheet must be sealed.

Fumigation chambers in buildings should have sealed sheet metal linings and gasketed doors. False floors are desirable for good gas distribution. A built-in blower is required to ensure circulation during treatment.

Use levels for both MB and EDB vary from 1/2 pound to 3 pounds per 1000 cubic feet of space, depending upon product temperature and the specific crop being treated. Treatment at 65°F or below is not recommended. The usual treatment time for both fumigants ranges from 2 to 4 hours.

Vapor-Heat Treatment

For certain crops that are injured by exposure to treatments that are lethal to the insect infesting the product (citrus fruits, mangos, papayas, pineapples, and a few vegetables), a water vapor-heat treatment may be substituted for fumigation. With this procedure, the fruits and vegetables are exposed to saturation vapor at 110°F that is mixed with a fine mist of water and air. Once the product reaches 110°F at its center, it must be held there for 8-3/4 hours to ensure death of eggs and larvae of fruit flies. Once treatment is finished, the fruits or vegetables are cooled as rapidly as possible. The vapor-heat treatment has the advantage of avoiding the use of toxic chemicals. However, the prolonged exposure to high temperature tends to reduce the subsequent life of the crop.

Cold Treatment

A third choice for meeting plant quarantine requirements is refrigeration of the product for a specified time. Controlled tests have determined that certain fruit infesting insects (Mediterranean fruit fly, Mexican fruit fly) will not survive sustained periods of low temperature. This finding has been applied to the sterilization of certain fruits imported to the United States from infested areas. The plant quarantine agency of the USDA has established time and temperature exposure requirements for the cold treatment of fresh fruit.

The following schedule is the required treatment for fruits from areas infested with the Mediterranean fruit fly (Ceratitis capitata):

10 days at 32°F or below

11 days at 33°F or below

12 days at 34°F or below

14 days at 35°F or below

16 days at 36°F or below.

Coatings

Surface coatings, mostly waxes, are applied to certain fruits and vegetables primarily to reduce moisture loss, and thus shriveling and wilting. With some products, an improved glossy appearance is the main advantage. Waxes are used for rutabagas, cucumbers, tomatoes, cantaloupes, peppers, turnips, sweet potatoes, citrus fruits, apples, and certain other crops.

Waxing alone does not control decay as is sometimes claimed, but waxes containing disinfectants, such as chlorin compounds or sodium orthophenylphenate, are effective for decay control.

Sprout inhibitors also may be incorporated into waxes. The common components of water emulsion waxes include paraffin, carnauba, candelilla, ouricouri, and beeswax. Rising costs of these natural waxes has led to increasing use of synthetic resins such as high-density polyethylene. These coatings are made from food grade components. The use level of waxes is approximately 2-1/2 gallons of wax for 400 boxes (about 8800 kg) of fruit.

For orange fruits, a food dye, Citrus Red No. 2 (1-[2,5-dimethoxyphenylazo]-2-naphthol), is applied. This dye is disolved in an organic solvent such as d-limoene, and the solution is emulsified in water. Federal law limits the residues of Citrus Red No. 2 to 2 ppm. The residues occur almost entirely on the outside of the fruit.

Grading

Grading, the sorting of fruits and vegetables so that the contents of each package will be fairly uniform, makes produce salable. Most volume buying of fresh produce is done on the basis of grade and size.

The USDA has established uniform grades for each important produce.

Sizing of much fresh produce is based on human judgment and is a manual operation. It may be done by sorters who select specific sizes from a belt and place them on special conveyors to be carried to bins for the packers. This method is commonly used for cantaloupes and large melons.

Mechanical sizers are also available for almost all fruits and vegetables. Practically all fresh market apples, citrus fruits, and tomatoes that are packed in central facilities are mechanically sized. Potatoes are usually marketed in mixed sizes with only very small and extra large tubers eliminated. However, some fancy packs, particularly for baking, are sized and sold by size.

Sizing by machine may entail only elimination of those units too small or too large for market acceptability, or it may be used to separate a number of sizes for special packs. Mechanical sizing is done by weight, diameter, or length.

Weight sizers are commonly fabric or steel mesh belts with holes for products of a certain size to drop through. They may have only one size hole, as for the elimination of unsalable small sizes, or they may consist of several sections with the smallest holes in the first section and increasingly larger holes in succeeding sections. This type is commonly used for sizing apples and mature green tomatoes.

Packing

A shipping container is primarily a handling unit to facilitate moving material from one location to another. It also provides some physical protection for the commodity, but such protection varies widely with the type of container.

A few states have established container standards through legislation. These regulations specify what types and sizes of containers can be used for specific fruits and vegetables. In some cases they also require approved containers for interstate shipment of produce, thereby prohibiting the movement of bulk produce. Other states do not have container specifications but do require that produce be shipped in containers recognized by the produce industry.

The sizes, shapes, construction, and materials of shipping containers are controlled principally by the railroads. These container

tariffs are developed and enforced by the Transcontinental Freight Bureau of the Association of American Railroads. The published tariffs are complete with pictures, specifications, and sizes of approved shipping containers. The tariffs specify not only what commodities may be packed in each container, but also how the containers are to be loaded in the rail car. Widely used shipping containers include burlap, cotton, or plastic mesh; ventilated plastic film bags; fiberboard cartons of full telescope (two-piece with two completely covering bottom pieces), partial telescope (top partially covering bottom piece), or flap-top types (one-piece); wirebound boxes of wood veneer or combinations of veneer and fiberboard; sawn and nailed wooden boxes; and molded plastic or plastic foam boxes with plastic or fiberboard lids or with a wrap-around plastic shrink film cover.

Pads of paper-covered excelsior, corrugated paper, foam plastic, or plastic film with entrapped air bubbles are widely used for protection from pressure-bruising in containers for table grapes, peaches, nectarines, and pears. The pads are used principally in wooden boxes, where they provide cushioning in the bottom of the box. However, the tight full-pack for soft fruits includes top or top and bottom pads for protection.

Liners of waxed chipboard or smooth plastic are often used in wooden boxes to prevent contact between the product and the sides and ends of the back.

Paper wraps for cushioning and isolating individual fruits are now used much less extensively for apples, peaches, nectarines, and pears than they were before the advent of cartons as shipping containers for these fruits. The cost of applying wraps to each individual fruit is one factor for the decline. Until recently, the use of oiled paper wraps or shredded oiled paper was essential for control of scald in stored apples. Currently, a diphenylamine dip after harvest is used effectively for scald control.

SECTION 5

RESULTS AND DISCUSSION OF POLLUTION PROBLEMS IN THE FRESH PRODUCE INDUSTRY

AIR POLLUTION

Air pollution problems arising from the handling of fresh produce are negligible, when compared to other industries or even with some food processing operations. Unpleasant odor associated occasionally with the preparation of fresh produce represents the principal potential air pollution. Generation of malodor that creates a local nuisance occurs during the onion curing process, and more obnoxious odor is associated with the disposal of egg-washing water. Because fresh egg cleaning is a year-round operation, it can be objectionable to the population surrounding the egg processing plant when the wash water disposal is not controlled properly.

Potential air pollution problems that may arise from the preparation of fresh produce covered in this study are as follows:

Crop	Unit operation	Pollution problem
Onions	Field drying/curing	Malodors
Grapes	Preservation	SO_2
Lemons	Ripening/storage	Ethylene gas
Nuts	Hulling	Ethylene gas
Apples	Storage	CO_2
Eggs	Washing	Malodors
Fish	Eviscerating	Malodors

The field drying and subsequent curing of onions requires 3 to 4 weeks depending upon climatic conditions. The unpleasant odor resulting from organic sulfide compounds creates only a local problem, and because these operations take place in the field, residential areas are not affected. Some artificial curing is performed under controlled conditions at central plants instead of the field, which could create a nuisance for the surrounding community. However, odor control in processing plants can be achieved with the same methods as recommended for dehydrated onion and garlic operations. Treatments of the contaminated air with activated carbon and other possible methods used in the onion-garlic drying industry are described in more detail in the food processing overview section of this study.

The air pollution problem resulting from the application of SO_2 for extending the shelf life of grapes is similar to that described in the

food processing part of this study under sulfuring treatments of dried fruits (J.L. Jones, et al, 1978). Emission of SO_2 causes unpleasant odor, and although the compound is recognized as safe (GRAS) for use in foods by the FDA, it may represent a health hazard to workers who are frequently exposed to these fumes. For this reason, the food application of SO_2 is limited or banned in several countries (for example, in West Germany and Japan), and effective and economical but less harmful substitutes are pursued by the industry.

Ethylene gas (CH_2CH_2) is applied to accelerate the ripening of lemons and certain other fruits. The application of a very low concentration of ethylene (0.05%) is effective to induce ripening. Although the use of ethylene requires certain precautions (it is an explosive if it is mixed with a certain concentration of oxygen or steam), it does not represent any direct pollution hazard to the surrounding area.

In controlled atmosphere (CA) food storage, refrigeration is supplemented by a modified atmosphere of reduced oxygen and increased CO_2 (2 to 5%) content. Such storage houses must be well sealed, and personnel entering the storage area for repair or inspection must be protected by air-supplying masks. However, these storage operations do not induce any measurable air pollution to the surrounding area.

One of the most obnoxious malodors may be created by improper disposition of egg-wash water. Wastewater generated during grading and packing of eggs contains residues from broken eggs, and an estimated 1 percent of the eggs crack and release organic material to the wash water. If this egg-washing water is sprayed untreated onto open fields or if a leakage occurs from evaporator beds, a very obnoxious malodor is generated. Therefore, before discharge, the water must be subjected to aeration, ozonation, filtration, and clarification treatments.

Unpleasant odor from fish preparation is created by enzymatic reaction related to the mechanisms of deterioration that are used by bacteria. Unpleasant odors derive from the breakdown products not absorbed by the bacteria. The effects of bacterial action may vary considerably, depending on the species of fish, the form in which they are landed, and the method used to protect quality. Fish such as mackerel or herring, which are caught close inshore, are stored on the vessel in the ungutted condition and without icing. The cleaning of such fish onshore creates greater amounts of waste and therefore more odor problems to the surrounding area.

Other fish taken in netting or trolling are eviscerated on the ship and protected aboard the vessel by icing and good sanitation practices. Consequently, they will cause insignificant odor problems, provided that bacterial contamination ashore is carefully controlled during unloading, sorting, and market preparation.

SOLID WASTES

Solid wastes from fresh-pack fruits and vegetables originate from washing, trimming, topping, sorting, grading, hulling, and shelling processes. The solid wastes include leaves, stems, hulls, shells, off-grade fruits, and other miscellaneous rejects. Major sources of solid wastes are given in Table 4.

These wastes are organic and highly perishable in nature. However, substantial preparation of fresh produce is completed in the field, and therefore the organic waste is disposed of there by returning it to the field. In central packaging operations significant waste material has a value if it is used as a by-product (as fuel or as feed) or used in processed food (e.g., fruit juice, apple sauce), if fresh produce packing is combined with canning operation.

However, unused fruit and vegetable wastes in central packing operations can cause fly and rodent problems, unpleasant odors, and water pollution from leachate. The overall quantity of solid wastes created by fresh fruits and vegetables is small within the waste load created by the food processing industry. In California, solid wastes from fresh-pack fruits and vegetables was estimated in 1967 at 409,500 tons, as shown in Table 5. This represents less than 20 percent of the solid waste generated by the entire food industry.

WATER POLLUTION

The market demands clean produce, so most fresh produce is washed after harvest to remove dirt, freshen the produce and reduce spray residues. Thus, several fresh fruit and vegetable handling operations are major water users as well as water generators. Wide ranges of wastewater volume and organic strength are generated per ton of produce handled. Preparation of some fruits does not include washing at all (grapes, watermelons), other crops are washed only occasionally when the produce is extremely dirty (cantaloupes, potatoes), while a number of operations require the use of large amounts of water from flume-transport within the plant, as well as for cleaning (apple, citrus).

Wastewater volume and organic strength vary among days of the operating season. Although significant quantities of water are used and disposed in the field for field-packed crops, there are many fruit and vegetable packaging plants located in moderate- or small-size communities that discharge water to municipal treatment plants.

Important unit operations that require the use of water in fresh fruit and vegetable packing are: hydrohandling, soaking, washing, rinsing, surface coating, and hydrocooling. Water use by the fresh produce handling industry is summarized in Table 6.

Water used for washing, fluming, hydrocooling of fruits and vegetables, and cleaning equipment is usually chlorinated to control

TABLE 4. MAJOR SOURCES OF SOLID WASTES GENERATED IN FRESH PRODUCE HANDLING AND THEIR UTILIZATION

Crop	Unit operation	Waste	Utilization
Apples	Hydrohandling, washing	Debris, dirt, leaves, etc.	
	Grading/sorting	Undersized and off-grade fruit	Juice, sauce
Tree nuts	Hulling	Hulls	Dye, cattle feed
	Shelling	Shells	Fuel, charcoal, sand-blasting ingredient
	Grading/sorting	Inedible kernels	Oil, feed
Citrus	Presizing	Small fruits, culls	Juice
	Washing	Dirt leaves, etc.	
	Inspection	Blemished fruit	Juice
Celery	Trimming	Outer leaves	Feed
	Washing	Soil, dirt	
Lettuce	Trimming	Soiled, diseased leaves	Feed
Melons	Washing (occasional)	Soil	
Onions	Topping	Cut-off leaves	
	Cleaning, grading	Loose scale, leaves, etc.	
Potatoes	Washing (occasional)	Soil	
	Sizing	Small tubers	Feed or canning
	Inspection	Off-grade tubers	Feed
Eggs	Machine loading	Broken pieces	
	Candling	Broken pieces	
	Packing	Inedible eggs	Processing
Fish	Beheading	Fish	Feed, oil, bone-meal
	Cleaning	Scale	Fish meal
	Eviscerating	Viscera	Fish meal, fish concentrates
	Filleting	Fish pieces	Processing frozen product
	Socking (oysters, etc.)	Shells	Fertilizer, feed

Source: SRI

TABLE 5. ESTIMATED QUANTITIES OF SOLID WASTES FROM FOOD INDUSTRY IN CALIFORNIA, 1967

Type of waste		Amount (tons)
Fresh-pack fruits and vegetables		410,000
Canned, frozen, and preserved fruits and vegetables		1,120,000
Canned fruits and vegetables	750,000	
Frozen fruits and vegetables	170,000	
Other preserved fruits and vegetables	200,000	
Meat processing		100,000
Dairy industry		69,000
Miscellaneous food processing		431,000
Total		2,130,000

Source: Cornelius, J., 1969. "Production and Disposal of Industrial Solid Wastes in California," California Vector Views, 10, 5.

bacterial contamination and to avoid odor problems. Recommended chlorine content in the water is between 2 and 5 ppm (as free chlorine) at the point of application. At this level of concentration, chlorine has no deleterious effect on the flavor, color, and nutrient content of fresh fruits and vegetables.

On the basis of all evidence reviewed, no hazardous pollutants (e.g., heavy metals, pesticides) occur in wastes discharged from fresh fruit and vegetable processing facilities.

Washing of eggs requires large usage of water. A significant portion of the water discharged by the egg producer is highly contaminated with saline and must be treated to prevent it from coming into contact with the underlying ground waters.

Reduction of wash water use by recycling systems cannot be initiated by this industry because of existing FDA regulations prohibiting it. (For more details, see discussion section 4 of Volume I of this report.)

Some experiments to recycle wash water in the citrus packing-line were conducted by Sunkist Growers Inc., and these are discussed in detail in Appendix G.

TABLE 6. WATER USE BY THE FRESH FRUIT, VEGETABLE, EGG AND FISH HANDLING INDUSTRIES

Crop	Unit operation*
Apple	Hydrohandling
	Soak, rinse
Grape	None
Tree nuts	Washing
Citrus	Washing
	Surface coating
	Precooling
Celery	Washing
	Hydrocooling
Lettuce	None
Melons	
Watermelon	None
Canteloupe	Washing (occasional)
	Hydrocooling
Onions	None
Potatoes	Water flume
	Washing (occasional)
Eggs	Washing
	Grading
Fish	Eviscerating, icing, preserving, preparation for market, prechilling
Oysters	Retorting
	Sucking
	Flotation, grading
	Blow washing
	Drum washing

* Use of water for normal equipment cleaning is not included.

Source:

PESTICIDES AND CHEMICAL PROCESSING AIDS

Fewer spray applications for insect and disease control are used today because more effective and less stable chemicals are available than those of arsenic and lead that were used 30 years ago. Thus, chemical residues are seldom present in unacceptable levels in the fruits and vegetables.

Spray deposits that cause unattractive appearances no longer present a problem. The addition of vinegar (0.4 percent acetic acid to the wash water) is sometimes used to reduce spray deposits on apples.

Chlorine compound is often applied as a germicide in the forms of chlorine gas, or sodium hypochloride in flume, washing, cooling, and equipment cleaning water at levels between 2 to 5 ppm or at 10 to 20 ppm. Sodium hypochloride is also used for the bleaching of walnut kernels.

Sodium o-phenylphenate (SOPP) is a fungicide commonly used in the washing of citrus fruits. When this compound is applied to the washing water, its pH must be controlled between pH 11.5 and 11.8 to avoid damage to the fruit. This is achieved by the addition of caustic soda (NaOH). Another fungicide, 2-amino butane, is also used in 1 percent aqueous solution in the flume water. Benzimidazole fungicides are also commonly used for citrus fruits.

Fumigants used for insect and disease control for citrus fruits, stone fruits, and some vegetables are methyl bromide (MB) and ethylene dibromide (EDB). Grapes are fumigated with sulfur dioxide gas prior to storage and are periodically refumigated with the same compound to control the fungus Botrytis cinerea.

Surface coatings, mostly waxes, are applied to such produce as citrus fruits, apples, and cantaloupes. The surface coating agents are water emulsion waxes of paraffin, carnaube, candelilla, or beeswax. These natural products are often substituted with lower priced synthetic resins such as high density polyethylene.

The food dye Citrus Red No. 2 (1-[2,5-dimethoxyphenylazo]-2 naphthol) dissolved in d-limoene solvent is applied to the surface of Florida oranges. The residue of the dye is limited to 2 ppm maximum by federal regulation.

Application of certain "growth regulating substances" is permitted to control sprouting of potatoes. Maleic hydrazide CIPC (isopropyl-N-(3-chlorophenyl carbamate) is frequently applied for this purpose.

Preparation of shell eggs requires the use of egg cleaning, destaining, and sanitizing compounds. Compounds used in shell egg preparation must be authorized by the USDA Meat and Poultry Inspection Program.

SECTION 6

APPLES

GENERAL INDUSTRY CHARACTERISTICS

The apple industry, once highly scattered geographically, is now concentrated into specialized areas of Appalachia, the Mid-Atlantic States, Michigan and Ohio, and the Pacific Coast or western region. Of these, the western region is the most important producing area in the United States.

Both total U.S. apple production and western apple production have shifted into specialized areas. Washington, California, and Oregon are the three most important producing states in the western region. Concentration in these three states has been attributable in part to the development of irrigation systems and higher yields compared to other western states.

Washington has been the most important apple producing state in the nation since World War I. The apple industry in this state has undergone dramatic structural changes since World War II as a result of internally and externally generated developments. These can be summarized as follows:

- An approximated 80-85 percent decline in the number of orchards and an eight- to tenfold increase in average orchard size
- A substantial increase in average yield per bearing tree, and development of a standard sized dwarf tree providing efficiencies in picking
- The concentration of production in a few varieties, namely, red, standard, Golden Delicious, and Winesap
- The decline of the terminal broker/auction function and the dramatic growth in direct retailer buying
- The adoption of the "piggy back" method of transportation (combination rail and truck) and mixed carloads of fruit
- The adoption of controlled atmospheric storage.

On the other hand, there are significant differences between the Washington apple industry and that in other major producing areas. For example:

- Washington, Oregon, and California apple packers have a higher proportion of oral or written procurement contracts than the industry in general. Similarly, packers in this area are more active in providing financial and management support to growers.
- Average storage time in Washington tends to be longer than in other producing areas, and as a result, use of controlled atmospheric storage is more prevalent than regular atmospheric storage.
- Most of Washington's apple produce is sold outside the region whereas most produce from other areas is sold in the same region or nearby.

This industry is seasonal with harvesting dates commencing in late June and ending in late November, depending on the region. Heaviest harvesting activity normally takes place from mid-September through early October in the major producing areas. The industry is dependent on unskilled labor for harvesting, with local labor content averaging 44 percent in the Northwest region, 53 percent in California, 20 percent in the Northeast, and 10 percent in the Lake States. The Northeast has the highest content of foreign national and offshore labor (~36 percent) followed by Appalachia (10 percent) and California (8 percent).

Per capita consumption of fresh apples has declined from 20.1 pounds in 1960-61 to 17.0 pounds in 1976, although during the period 1967 through 1976 per capita consumption has remained relatively static, fluctuating from a high of 18.3 pounds in 1970 to a low of 14.5 pounds in 1973. Production during this period has increased from 3135.2 million pounds to 3,865.1 million pounds; an average annual growth rate of 2.4 percent.

Apple varieties commonly recommended for eating fresh are Delicious, McIntosh, Golden Delicious, Stayman, Jonathan, and Winesap.

UNIT PROCESSING OPERATIONS

All apples that are sold in the fresh fruit market are hand-harvested to keep them free from severe bruises, cuts, and other damage. Harvesting aids are used, however, to improve efficiency, such as man-positioning platforms moved by hydraulic device, combined with conveyor equipment to carry picked fruit to pallet bins.

Lug boxes are used as field containers for apples. Fruits are emptied from field containers into water or cleansing solutions. The soak time in the tank, followed by a rinse with clean water as apples are conveyed to the packing line, is usually sufficient to remove the dust and dirt accumulated in the orchard and during transport to the packing house. Since insect and disease control is now possible with fewer spray applications, chemical residues are seldom present in hazardous amounts on any of the apples at harvest time. When visible

residues of insecticides, fungicides, or calcium sprays are objectionable at harvest time, brushing and washing are used to clean fruit surfaces.

The increasing use of high sprinkler heads for irrigation in apple orchards sometimes causes a problem in the form of mineral deposits on apples. The deposits, from the evaporation of large amounts of water, are unsightly and very difficult to remove by the usual cleaning methods. The addition of 0.4 percent acetic acid to the wash water is recommended to reduce these deposits to an acceptable level.

The use of surface coatings on apples is increasing. The coating materials in use include petroleum and vegetable oils and waxes in various combinations, such as carbanauba, paraffin, and liquid polyethylene. The purpose of this coating is to give a bright appealing finish to the fruit. The weight of waxed fruit, due to moisture loss, does not differ significantly from that of untreated fruit.

After cleaning, sorting and sizing are the next operations in packing houses. Most sorting operations begin with the removal of fruits too small for packing and separation of trash such as leaves and spurs.

Water has been used as handling medium for fruits for many years. Dumping field crates of fruits into a water or a soap solution tank has long been recognized as desirable for minimizing physical injury to the fruit, and for removing dirt and residue. The flotation of apples from pallet boxes submerged in water became general practice in the early 1960s and represents a major advance in apple handling. The success of flotation removal plus the potential advantages of presorting, presizing and bin refilling for bulk storage led to the development of complete hydrohandling systems.

The hydrohandling equipments vary in detail but installations for handling apples are based on the following principles. After removal of apples from the submerged pallet box, the fruit is moved through a shallow water tank to a small fruit eliminator. Undersize fruit floats through the spaces in the sizing chain and is removed by a lateral stream and conveyor to pallet bins. The remaining fruit is floated to a roller conveyor that removes it from the water to a sorting line. Workers in the line remove culls and off-grade fruits to chutes or overhead belts. The graded fruits are then returned to shallow tanks where different diameter sizers separate the fruit into two or three sizes and remove each size separately to accumulators. The boxes are refilled in hydrofillers, which lower water level in the pallet boxes as the waterborne fruit enters. Filled boxes are removed when the water level is fully below the container. The filled box is then removed from the hydrofiller and an empty box is put in place.

Apples to be stored in the pallet boxes are usually flooded with a mold inhibitor solution and then drained after removal from the hydrofilter.

The present trend is to store apples in bulk, and to pack them during the marketing period. Apples are usually not precooled for shipment, since most of the crop is stored in cold, and therefore cooling is achieved in a cold storage room at only moderate cooling rates, and the storage temperature is reached over several days.

The commercial storage of apples is usually done in atmospheres lower than normal in oxygen (controlled atmosphere or CA storage), and containing appreciable amounts of CO_2. This storage was developed during the last 20 years and it offers important gains in extending the market life of certain apple varieties. By elevating the storage temperature to approximately 40°F (5°C) and altering the composition of the atmosphere, it is now possible to eliminate chilling injury, a common disorder of apples associated with low storage temperature. The recommended conditions for the storage of the important cultivars of apples grown in the United States are given in Table 7. CA storage adds several months to the storage life of some cultivars of apples, notably McIntosh, and gives longer shelf-life to the fruit.

TABLE 7. CARBON DIOXIDE, OXYGEN, AND TEMPERATURE REQUIREMENTS FOR CONTROLLED ATMOSPHERE STORAGE OF APPLES GROWN IN THE UNITED STATES

Cultivar	Carbon dioxide (%)	Oxygen (%)	Temperature (°F)
Cortland*	2-5	3	38
Delicious†	1-2	2-3	30-32
Golden Delicious†	1-2	2-3	30-32
Jonathan	3-5	3	32
McIntosh*	2-5	3	38
Northern Spy	2-3	3	32
Rome	2-3	3	30-32
Stayman	2-3	3	30-32
Newtown	7-8	2-3	38-40

* Cortland and McIntosh are stored in 2 percent CO_2 the first month and 5 percent thereafter.

† Delicious and Golden Delicious in Washington State are stored at 1 to 3 percent oxygen rather than at 2 to 3 percent.

Source: Ryalls, A. L., and W. T. Pentyer, 1974. Handling Transportation and Storage of Fruits and Vegetables, Vol. 2 (AVI Publishing Co., Westport, Conn.)

The final step in the preparation of fruit for the fresh market is placement in the sales or shipping containers. Fiberboard containers are largely used today as shipping containers in most apple producing areas. Some old-fashioned wooden boxes are still used in the East. Cartons for apples come in several sizes, but most have a capacity of about a bushel, with net weight of fruit ranging from 36 to 44 pounds (16.3 to 20 kg), depending on types of pack and cultivars of apples.

The cartons may be bulk-filled for marketing, but more frequently the apples are place-packed in molded trays; individual fiberboard cells are used as master containers for bagged or tray-packed fruits.

Unit operations in the apple industry and their contribution to pollution are summarized in Table 8.

TABLE 8. CONTRIBUTION OF APPLE INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit Operations	Water	Solids
Soak tank	X	X
Rinse	X	
Water Flume	X	
Surface coating		
Sizing and grading		X
Storing		
Packing		

Source: SRI

Utilities needed by fresh apple processors are electricity and water. Water is used in fresh apple handling in the continuous flow-dumper, for rinsing, and in the water flume. In the larger packing plants, water is usually recycled and replaced only periodically. The flume water is chlorinated and some detergent is added to remove dirt.

Surface coating compounds are applied after washing; therefore, they do not contaminate the water.

One of the largest fresh apple packers in the State of Washington packs 10,000 to 40,000 cartons of fruit per day and requires the following quantities of water: 5,000 gallons (18,900 liters) in the presizing flow dumper, 1,800 gallons (6,800 liters) per day for each of three vertical spray-washers, 2,800 gallons (10,600 liters) in the flume, and 500 gallons (1,890 liters) per day in the final washer. The water is recycled and replaced every two weeks.

SECTION 7

GRAPES

GENERAL INDUSTRY CHARACTERISTICS

Grapes are grown commercially in 13 of the 50 states. The industry is separated into three general regions over the country according to the type of grape grown: (a) regions with European-type grapes (Vitis Vinifera), including mainly California, Arizona, and lower Texas; (b) regions with native American-type varieties (V. labrusca, or its hybrids with V. Vinifera), consisting of an area east of the Rocky Mountains and north of the Gulf States plus the Northwest and California, which have significant commercial acreages, and (c) regions with Muscadine grapes (V. Rotundifolia), including the South Atlantic and Gulf States.

Grape production for the fresh market has increased slightly from 1967 to 1976 from 431,000 tons to 453,000 tons. The increase has been about the same as population; consequently, per capita consumption has been, on the average, about 3 pounds. These trends are not very significant because several varieties of grapes can be used for wine, raisins, or table use. Depending on the prices in each of the markets, the grapes will be diverted to markets that will give the grower the best return.

The vinifera grape, largely grown in California, constitutes about 93 percent of the grapes produced in the United States. Thompson Seedless grapes account for more than 50 percent of the grapes supplied for the fresh market, with Emperor, Tokay, and Ribier following in order of importance. These grapes are produced primarily in the central valley of California.

UNIT PROCESSING OPERATIONS

Table grapes are hand-harvested, and more than 80 percent of the grapes are packed in the field. The trend has been toward field packing and away from packing shed operations because of the perishability of table grapes related to time and shipping in bulk to packing sheds. Grape pickers bring the grapes to roadside where grader-packers fill and close the cartons. In the case of Thompson Seedless, a crew of four will pick and pack 200 cartons (23 pounds or 10.4 kg each) in 9 hours. The other varieties require more time since color selection and culling are more critical.

From roadside, the cartons are shipped to a shipping station where they are inspected, fumigated, cooled, and shipped to market. The industry is becoming more vertically integrated with grower-packer-shipper being one organization. The marketing function is performed by the organization's own sales desk or by sales agents or brokers. Cooperatives are an important element in the grape industry. Blue Anchor, Inc., a grower cooperative, probably controls 20 to 25 percent of the fresh grape shipments in California.

The grape harvest varies by variety and location. In California, the harvesting of early varieties can start as early as May 20 and, with weather permitting, the harvest can last until mid-December.

Most California table grapes are marketed 2,000 miles (1,250 km) or more from the vineyards. Transportation is by refrigerated rail cars or by air. Proper time of harvesting is judged by the sugar content, using a hydrometer. It is usually necessary to go over a vine three or more times to harvest most of the table grapes at the proper stage.

Many varieties of the vinifera species can withstand the rigors of handling, transport, and storage required of table grapes for wide distribution over a long marketing period. Almost all of the table grape is precooled and much of it stored for varying periods before consumption.

Recommended storage temperatures are 30 to 31°F (-2 to -1°C). A humidity of 87 to 92% is recommended. Some storage plants in California have precooling rooms where grapes are cooled to 36° to 40°F (2-5°C) in 20 to 24 hours before they are placed in storage. Precooling to 40-45°F (5-7°C) is advised for grapes that are to be in transit a day or two before reaching storage. After the fruit has been precooled, the air velocity is reduced and the grapes are fumigated with sulfur dioxide (SO_2) gas to prevent or retard decay. It has become common practice to accumulate packed fruit in the precooler during the day packing and to fumigate the fruit in the evening. In this way, precooling is not delayed and fumigation can be done after most of the working crew has left. Because grapes can be injured they should be exposed to only the minimum quantity of SO_2. The amount of fumigant required depends on the decay potential and condition of the fruit, the amount of fruit to be treated, the type of containers and packaging materials, the air velocity and uniformity of air distribution, size of the room, and losses from leakage and sorption of walls. Under favorable conditions, SO_2 concentration of 0.5 percent by volume for 20 minutes is adequate.

It is necessary to refumigate grapes at weekly intervals in storage to prevent field infections by Botrytis cinerea from spreading to adjacent sound fruit. For refumigation, a basic concentration of 0.1 percent for 30 minutes is adequate.

Wooden lug boxes are the principal shipping containers for European-type table grapes. Until recently, the L.A. lug, which holds about 28 pounds (12.7 kg), was standard. Currently several sizes are used, with net weights varying from 18 to 28 pounds (8.1 to 12.7 kg). One of the newer lugs has beveled corners to facilitate air circulation. Another innovation is the TKV lug, which has wooden ends and a laminated (wood veneer-kraft paper) wrap-around piece for sides and bottom. Most of the lugs are closed with a veneer lid, with end cleats to compensate for some bulge when the filled containers are stacked.

The standard lug pack was satisfactory for domestic marketing, but when subjected to long periods without SO_2 treatment, as in export shipments, decay was often excessive. The sawdust pack in wooden chests holding about 34 pounds (15.4 kg) of grapes and about 10 pounds (4.5 kg) of sawdust has become the principle export container for table grapes. If the chests are to be stored before shipment, they are packed with a small layer of sawdust beneath the lower layer of fruit to permit SO_2 fumigation during storage. Just before shipment the chest is filled with sawdust. A small amount of sodium bisulfite is usually mixed with the sawdust to release some SO_2 during transport.

Unit operations and their contribution to pollution are summarized in Table 9.

TABLE 9. CONTRIBUTION OF GRAPE INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids	Air
Field packing			
Precooling			
Fumigation			X
Storing (with periodic refumigation before shipping)			X

Source: SRI

The only utility needed by fresh grape processors is electricity. Water is not used in fresh grape handling.

Sulfur dioxide contamination of the air surrounding the fresh grape storage area is the only potential pollution problem in this industry.

SECTION 8

TREE NUTS

Two varieties of tree nuts, almonds and walnuts, were selected for study. While this study is oriented to fresh products, nuts are processed to some degree prior to marketing--hulling, drying, fumigating, bleaching, sorting, shelling, and packaging. Nevertheless, the industry considers the nuts to be fresh nuts after these processes.

ALMONDS

General Industry Characteristics

All the commercial acreage of almonds is in California, principally in the central valley, in a belt about 700 miles (438 km) long. Between 1957 and 1976, production increased from 76,600 tons (in-shell basis) to 233,000 tons. In 1976, there were 256,700 bearing acres and 79,300 acres of nonbearing trees. Trees begin bearing after 3 years; however, a tree is considered of commercial bearing age only after it reaches 6 or 7 years.

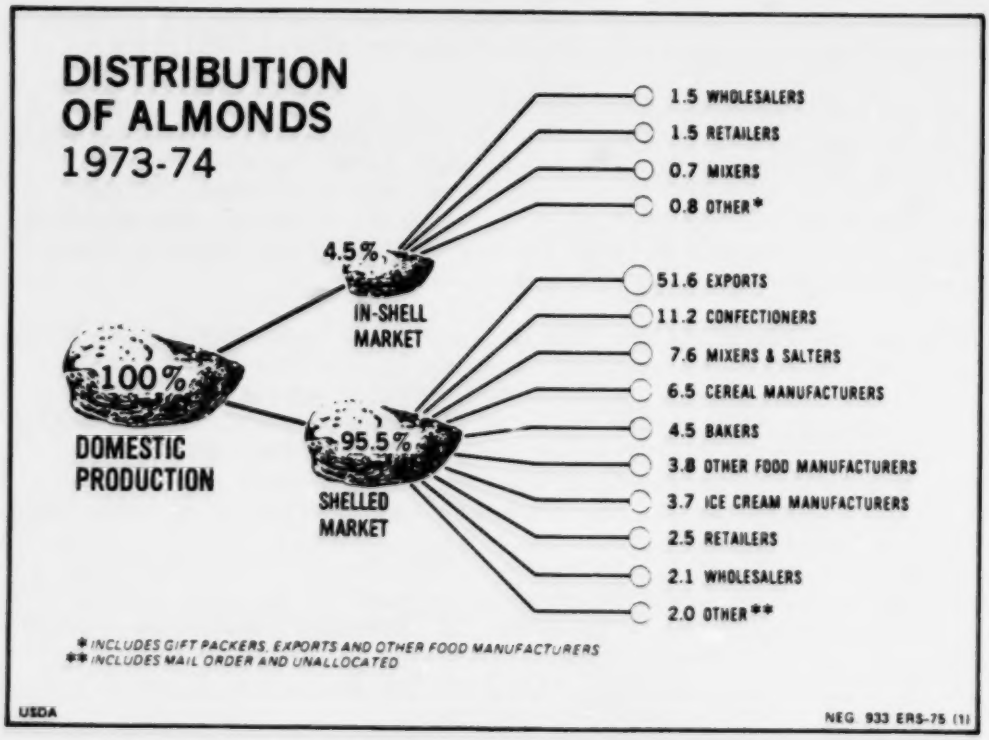
The harvest season runs from about August 5 to November 15 and the crop year begins July 1 and ends June 30 the following year.

About 65 percent of the crop is processed and marketed by the California Almond Growers Exchange, a cooperative. About 27 percent is processed and marketed by four major companies, one a cooperative, and the remainder of the crop is handled by six very small operations.

Per capita consumption has increased from 0.31 pounds (0.14 kg) in 1967 to a record high of 0.43 pounds (0.20 kg) in 1976 (shelled basis); however, shipment for domestic use accounts for only 38 percent of the industry's shipments. The remainder is exported. The large increase in U.S. production has been made possible by the industry's successful marketing efforts in foreign countries. Figure 1 shows the flow of processed almonds to various market outlets in 1973-74.

Unit Processing Operations

Harvesting starts when almonds in the shady portions of the tree show shriveling and cracking of the hulls. When they are ripe, tree nuts fall to the ground. However, when they drop unassisted, the harvest covers such a prolonged period that the nuts are commercially unsatisfactory. The usual harvesting procedure is to knock the almond to the ground, usually with mechanical shakers or knockers.



SOURCE: USDA, Fruit Situation, ERS, March 1975, p 53.

SA-5619-60

Figure 1. Distribution of almonds 1973-74

After several days of drying on the ground the almonds are picked up with the hulls still attached to the shell. Most of the commercial almond orchards now use inertia limb shakers for nut removal, windrowers for concentrating, and pick-up machines for gathering the nuts. They are then run through the huller to remove the hulls; however, practically all of the shells remain intact. After hulling, the nuts are sacked or loaded into bulk bins and taken to the receiving station.

Growers usually deliver their crops to the cooperative in the unshelled form through local receiving stations. The cooperative supplies its members with burlap bags that have been vacuum-cleaned, repaired, and fumigated. Where feasible, bulk handling of growers' deliveries is accomplished in pallet boxes of approximately one-ton capacity. These are designed for completely mechanized handling.

The nuts are then dried in almond driers or dehydrators to the point where they can be broken without bending the kernel and then are delivered to the processing plants. At that point the almonds are either shelled if they are to be sold as kernels or bleached if they are to remaind intact and sold as shell almonds. However, except for a relatively small quantity sold in mixed nuts during the holiday season, practically all are now marketed as shelled nuts.

Almonds are assembled for shelling in huge storage bins; from these they pass to a battery of cracking machines with a capacity of 175 in-shell tons per day. The kernels are mechanically separated from the shells and represent more than half the almonds by weight. The cracking percentage varies with different varieties. By passing through an electric eye device, kernels that are broken, chipped or discolored, along with foreign material, are separated and diverted to special uses.

In-shell almonds will retain good condition and flavor for 7 to 8 months at room temperature if they are reasonably dry when stored and the room humidity is below 70 percent. If prolonged storage is required for in-shell almonds, they should be held at 50°F (10°C) or below, and will usually remain in excellent condition for as long as 2 years at 32°F (0°C) with about 75 percent humidity.

The perishability of almonds is increasing by shelling. Air storage at 32°F (0°C) with 60 to 75 percent relative humidity is usually satisfactory for 15 to 16 months.

Shelled almonds stored under vacuum maintain good flavor and color for 20 to 24 months at 50°F (10°C). The vacuum process is now widely used for the preservation of roasted and variously flavored almonds, which are marketed in consumer-size metal and glass containers. Some packaging materials such as pliofilm and polyethylene should be avoided because they import an undesirable odor to the nuts.

WALNUTS

General Industry Characteristics

More than 99 percent of U.S. commercial walnut production is in California and is centered in the San Joaquin and Sacramento Valleys. A small acreage of walnuts is found in the Willamette Valley of Oregon. Production has increased from 98,000 tons (in-shell basis) in 1967 to 183,700 tons in 1976. In 1976 there were about 169,700 acres (68,678 hectares) of commercial bearing acres in California and 35,900 acres (14,529 hectares) of nonbearing trees. Trees begin bearing at 4 years and reach commercial bearing age at 8 or 9 years.

The harvest season runs from September 15 to December 30 while the crop year begins July 1 and ends June 30 the following year.

In 1976, about 70 percent of the walnuts were sold shelled compared to 42 percent in 1973-74. The distribution of walnuts during the 1973-74 season is shown in Figure 2. Walnuts are used primarily as a food ingredient by households as well as industrial users.

About 53 percent of California walnuts are handled by the Diamond Walnut Growers, Inc., a cooperative. Other major companies are Maifair Packing, Continental Nut, Guerra, and several smaller operations.

Per capita consumption has increased from 0.35 pounds (0.16 kg) (shelled basis) in 1967 to 0.53 pound (0.24 kg) in 1975. Exports accounted for about 25 percent of the industry's shipments in 1975 and is the fastest growing outlet for the industry.

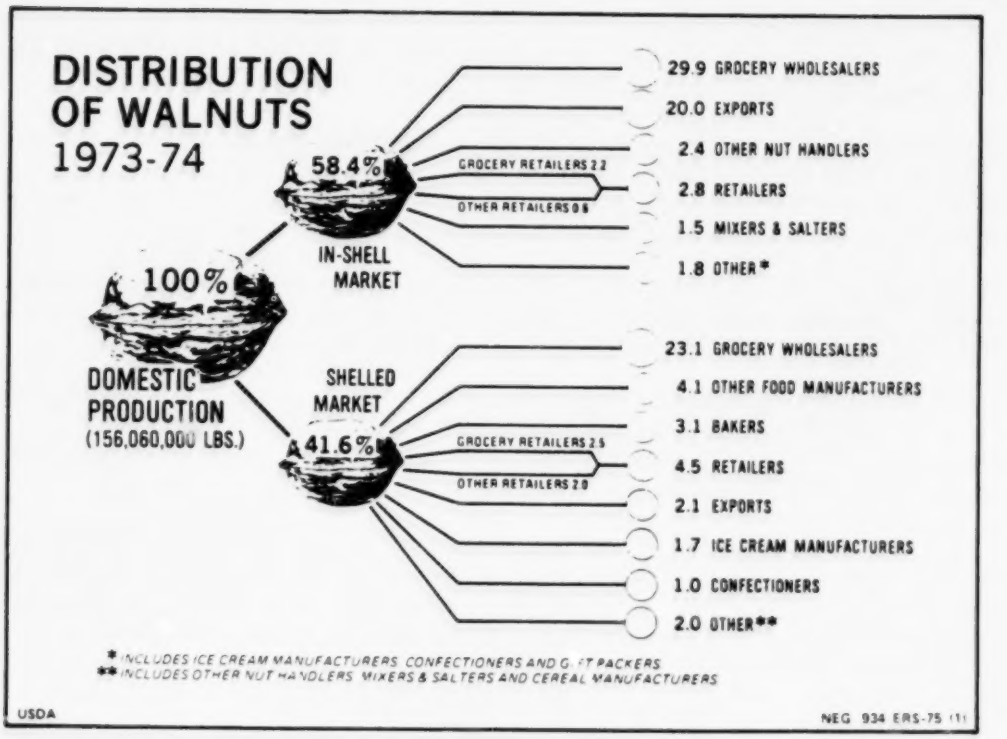
The only commercially important walnut is the English or Persian, Juglans regia, which is grown for the most part in California and Eastern Oregon. More than 80 percent of the walnut crop is handled by Diamond Walnut Growers Inc. Facilities of this association are located in Stockton, California.

Unit Processing Operations

Walnuts drop naturally over about a 2-month period. Trees are shaken by mechanical shakers, before the nuts drop naturally, in order to obtain the highest quality. The currently used method of harvest involves mechanical trunk or limb shakers, windrow machines to concentrate the nuts between rows, and pick-up machines to gather the windrowed crop. The nuts are hulled and dried immediately after shaking to avoid damage from rain or fog, which can increase the percentage of culls. Hulling is done by hand or by machine.

Once the kernel is mature, the biggest obstacle to harvesting is the large amount of green "sticktights"* that fall during the first

* Walnut with hull sticking to the shell.



SOURCE: USDA, Fruit Situation, ERS, March 1975, P.52.

SA-5619-61

Figure 2. Distribution of walnuts 1973-74

shaking. While water-sweating can be used to assist in removing the hull, it is not always satisfactory. Use of ethylene gas is more rapid and effective, and has been used successfully in the warm interior districts of Southern California. The green nuts are separated out and placed in an airtight bin equipped with forced draft ventilation. The gas is injected at the rate of one cubic foot of ethylene to 1,000 cubic feet of air with temperatures ranging between 70° and 80°F (21 and 27°C). The bin is ventilated with fresh air every 12 hours for 20 minutes to 1½ hours; regassing is done after each ventilation. Treatment is continued until 96 to 98 percent of the hulls are removed, which requires 24 to 72 hours.

Spray applications of 500 to 1,000 ppm ethephon (2-chloroethylphosphoric acid) 2 to 4 weeks before harvest have also been used to aid mechanical harvest. As a result of such spray applications, hulls dehusc readily, and complete nut removal with single mechanical shaking occurs as much as 3 weeks earlier than normal harvest.

The nuts are washed after the hulling to remove the juice of the crushed hulls, which otherwise will stain the shell and make bleaching difficult or impossible. Large, cylindrical drums are used with coarse wire netting to wash the nuts. The nuts are revolved in this cylinder under a stream of water for 2 to 3 minutes.

After hulling and washing, the nuts must be dried immediately to remove excess moisture from the kernels and shells. Nuts adequately dried should average about 6 percent moisture. Use of dehydrators has replaced sun drying. Forced, heated air is sometimes used, but prolonged drying must be done at relatively low temperatures (under 110°F or 43°C). However, final drying before cracking can be accomplished quickly by the use of much higher temperature air on a belt trough dryer, at 200°F (93°C). At this temperature, moisture can be reduced to 4.2 percent in 17 minutes.

After curing, the nuts are delivered to a local packing house. On reaching the packing house, the nuts are passed under a vacuum hood that removes the "blanks" or improperly filled nuts. Nuts with full kernels pass on to a belt where they are hand-hulled, and the obviously imperfect nuts are removed. The nuts then pass through a revolving drum containing a bleach solution of sodium hypochloride for 2 to 3 minutes. The bleach is harmless to humans and the kernels; it removes dirt and stains, leaving the nuts uniformly bright and clean. The nuts then pass to a belt where those nuts with imperfections revealed by the bleaching are picked out (e.g., wormy, moldy). The nuts are then sized mechanically into three standard grades (large, medium, baby). Each size grade of nut is run through a large thoroughly ventilated bin where the moisture that was absorbed in the bleaching process is removed. From the drying bins, the nuts pass on to another culling belt; then they are individually brand-labelled and packed mechanically into 1- to 2-pound cellophane bags or larger cartons. Over 80 percent of the in-shell walnuts are marketed in cellophane bags; the rest are packed in bulk cartons.

Many of the walnuts picked out as culls have good kernels and are cracked along with others by machine. The kernels are separated electronically from the cracked nuts on a color basis, and are sold as shelled walnuts, which constitute about 40 percent of the crop.

Kernels are sold in 4- and 8-ounce (113 and 226 grams) vacuum cans. In vacuum canning, machines do the filling, weighing, pulling of vacuum, and sealing. Kernels not used in consumer packages are packed in cartons for commercial use in ice cream, cookies, cakes, and other prepared foods.

Inedible kernels and shells are processed into various by-products (after a wet separation technique removes the nutmeat residues) such as oil for paints and walnut meal for poultry and cattle. A high percentage of shells are burned in the plant's furnaces for fuel. Part of the shells are sold for sand blasting uses. Walnut hulls are used in dye fabric for rugs and Japanese style dresses.

Properly dried in-shell walnuts will remain in good condition for a year or more at 32°F (0°C) with 60 to 75 percent humidity. There are no critical temperatures for storing nuts. Other conditions being equal, the lower the temperature, the longer the shelf life. Life may be extended from two to three times with each 20 degree (11°C) drop in temperature. The freezing point is 14°F (-10°C) for walnuts. In-shell walnuts can be kept at temperatures of 50°F (10°C) or above for only 6 months or less. Shelled nuts to be held from one harvest season to the next, without appreciable loss in quality, must be held at 36°F (2°C) or lower; those to be held for 6 to 9 months must be kept at 48°F (9°C) or lower, and all nuts stored for 4 to 6 months should be held below 68°F (20°C). The period of storage, at a given temperature, is doubled if the nuts are unshelled.

Much research has been done with various antioxidants in attempts to control rancidity in shelled walnuts during storage and marketing. The chemical antioxidants BHA and BHT, when used in vegetable oil and applied to shelled nuts, reduce the oxygen absorption by approximately two-thirds. A BHA+PG formulation is even more effective in reducing oxygen absorption.

All nuts readily absorb odors and flavors from the atmosphere and surrounding products. Certain gases such as ammonia react with the tannin in the seed coats of nuts during curing, and turn the nuts black. For these reasons, the atmosphere in the nut storage room must be free of all odors.

Cellophane is the preferred packing material for consumer size packages because both Mylar and Saran films contain a static charge that causes the chaft from walnut meats to cling to the surface of the package. Laminated aluminum foil pouches, sealed gastight, are also used for packing walnut meats.

Tree-nut industry unit operations and their contribution to pollution are summarized in Table 10.

TABLE 10. CONTRIBUTION OF TREE NUT INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Almonds		
Drying on ground		
Huller		X
Drying		
In-shell		
Storage		
Shipping		
Shelled		
Cracking		X
Sorting		X
(Bleaching, roasting, flavoring)	X	X
Packing		
Storing		
Shipping		
Walnuts		
Hulling (hand or ethylene treatment)		X
Washing	X	X
Drying		
In-shell		
Grading, sorting		X
Bleaching	X	X
Fumigation		
Packaging		
Storage		
Shelled		
Fumigation		
Size grading		
Shelling		
Sorting		X
Inspection		
Dried		X
Antioxidant treatment		
Fumigation		
Packaging		
Storing		
Shipping		

Source: SRI

Utilities needed by nut processors are gas, electricity, and water and refrigeration. Only insignificant amounts of water are used in the fresh nut processing operations when in-shell walnuts or shelled almonds are bleached. The hulls or almonds are used as cattle feed, and the shell material is used either for charcoal manufacture, or burned as a fuel in the roasting operation. Ethylene gas for dehulling walnuts and fumigation of the nuts present potential air pollution problems.

SECTION 9

CITRUS FRUITS

GENERAL INDUSTRY CHARACTERISTICS

Oranges, lemons, and grapefruit were the citrus fruits selected for study. All the commercial crop for the fresh market is produced in California, Arizona, Texas, and Florida. The relative importance of these growing areas in supplying the fresh market varies by type of fruit; consequently, each type will be considered separately.

Oranges

Oranges produced in Florida are primarily used for processing rather than as fresh produce. Approximately 93 percent of the oranges are processed into orange juice. In California and Arizona the reverse is true, with 64 percent of the crop going to the fresh market, whereas in Texas the crop is divided about equally between processing and the fresh market. In total, California-Arizona shipments account for about 67 percent of total fresh orange shipments, Florida accounts for 27 percent, and Texas accounts for 6 percent.

California-Arizona production for the fresh market is dominated by the navel variety of oranges, which is the preferred orange for eating and accounts for about 38 percent of the oranges shipped to the fresh market. Valencia oranges from California-Arizona is the other major variety and account for about 29 percent of the shipments.

In Florida, about 55 percent of the oranges are of the early and midseason variety and the remainder are Valencias.

Production of oranges for the fresh market has shown no significant trend from 1967 to 1976 and has averaged about 3,900 million pounds (1,770 million kg) during the past 3 years. Per capita consumption has declined from 18 pounds (8.2 kg) in 1967 to about 15 pounds (6.8 kg) in 1976. California-Arizona and Texas production for the fresh market has been increasing, but this increase has been offset by a decline in Florida production.

The movement of oranges from harvest to packer to wholesaler and retailer is different in Florida than in California-Arizona. The Florida orange industry is such that many of the major marketing and other related policy decisions are generated and implemented at the processor level. Hence, the share of the crop channelled through fresh outlets, and the resulting fresh fruit prices, are dependent upon

processing activities. Returns to growers in effect are determined by returns to processors.

Figure 3 is a flow diagram of the marketing channels for Florida fresh oranges.

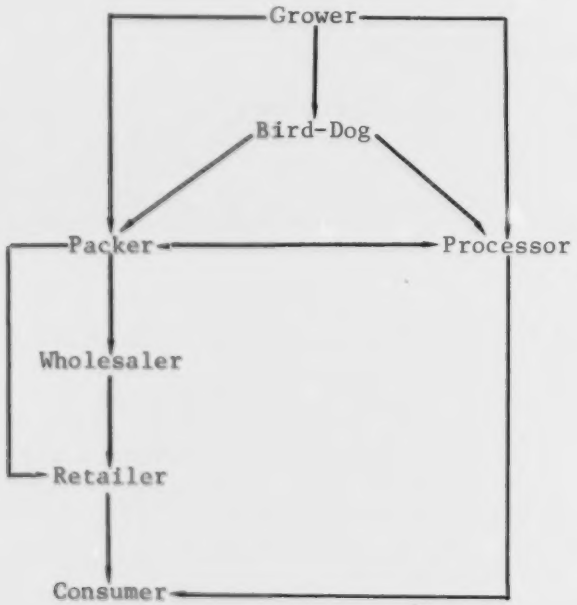


Figure 3. Marketing channels of Florida oranges.

Growers and fresh fruit packers have integrated by forming cooperatives. There are four types of cooperatives in the Florida citrus industry. These are:

(1) Cooperatives where fresh fruit packinghouse eliminations and some direct grower shipments are processed.

(2) The cooperative processor, where packinghouse eliminations and some direct grower shipments are processed.

(3) Centralized cooperatives that receive both fresh and processed fruit.

(4) Federated cooperatives, which are essentially centralized selling cooperatives that only market the production (fresh or processed) of the individual member packer or processor.

Cooperatives have also been formed that are affiliated with particular corporations. They are classified as cooperative fruit associations. The cooperative carries out the procurement function and the corporation performs the processing marketing function.

Fruit is received at the packing/processing plant on a priced or nonpriced (deferred price) basis. Priced fruit may come from individual growers but it comes typically from the intermediate handler or "bird-dog." Purchase of the fruit may be made on a bulk basis or on a price-per-box basis. Fruit that is priced by a deferred pricing arrangement goes through corporate participation plants or cooperatives. The price realized for this product depends on the profits of the packer/processor and the method of price determination.

Florida citrus producers and shippers operate under a federal marketing agreement that establishes standard grades for fresh fruit entering interstate commerce. The state Citrus Code establishes minimum maturity standards for fresh fruit. All firms who take title to fruit for resale as specified by the Florida citrus code must be licensed and bonded.

The California-Arizona orange industry is dominated by Sunkist Growers, Inc., a grower cooperative. About 80 percent of California-Arizona orange production is handled by this organization. The organization of Sunkist Growers, Inc., includes its member growers, local associations, district exchanges, and the affiliated Fruit Growers Supply Company. About 8,000 citrus growers in California and Arizona are members of the Sunkist Growers, Inc., and its affiliated organizations. These growers are responsible for performing all cultural practices in the production of citrus. All property rights or interests in Sunkist Growers, Inc., are held by member-growers.

A local association is a nonprofit cooperative association of growers. It represents its members in the district exchange and in Sunkist Growers, Inc., and usually provides packing services. Fifty local associations have a combined membership of about 4,000 growers. Local associations provide facilities for assembling, washing, grading, and preparing growers' fruit for market. The fruit is physically pooled and final pooling and distribution of proceeds is made to growers.

The 4,000 growers, who use about 50 licensed packers, must be direct members of a cooperative district exchange. The licensed packers are restricted to picking, packing, and shipping fruit as authorized by Sunkist Growers, Inc. All marketing functions for these growers are conferred on the district exchange and Sunkist Growers, Inc. There are 20 district exchanges in the Sunkist organization, and these are composed of growers who have their fruit packed by licensed packers, or of associations of growers operating as local associations, or both. Grower-members participate directly in representing and voting, in handling and distributing sales proceeds, and in allocating property rights. They reserve the right of final decision on price, destination, and transportation until after the sale has been made by Sunkist.

The California-Arizona orange industry operates under Federal Order (F.O.) 907 for navel oranges and F.O. 908 for Valencia oranges. These orders regulate permissible size and weekly volume. All shipments to markets in the United States and Canada are covered by these orders. Marketing orders for each variety are supervised by industrywide administrative committees that recommend weekly volumes of shipments and compute a prorate base and allotment for each shipper. The committees consist of six growers, four handlers, and one member not directly connected with the citrus industry.

Grapefruit

Historically, Florida has been the dominant grapefruit producing area in the United States, with approximately 75 to 80 percent of the crop. Structural changes affecting the industry in Florida can be summarized in terms of:

- An increase in yield per acre that is greater than the other major producing areas. Florida grapefruit yields reached a high of 21.3 tons (19,340 kg) per acre in 1966-67, up from 13.3 tons (12,076 kg) per acre in 1954-55. Recently yields have remained relatively stable at 17 tons (15,436 kg) per acre.
- The continuing interdependence of fresh grapefruit production with that of processed grapefruit. Florida accounts for approximately 80 percent of processed grapefruit, and grapefruit for processing now represents approximately 60 percent of total production versus less than 50 percent in the late 1950s.
- A relative scarcity of land as urban sprawl consumes agricultural land previously used for producing grapefruit.
- The existence of two separate and distinct production areas--the Indian River district and Interior Florida. Between these two areas, there are product differentiations, differences in distribution channels, and separate federal marketing orders.
- The growth of direct retailer buying changing the structure of grapefruit packing, communication facilities, and types of selling efforts. Direct retail buying now accounts for approximately 80 percent of the crop.
- The effects of freezes in 1957-58, 1962, and 1976, which have necessitated new plantings and some disruption to production.

Per capita consumption of fresh grapefruit has declined marginally from 10.1 pounds (4.6 kg) in 1956-58 to 8.9 pounds (4.0 kg) in 1974-76. However, consumption per capita during the period 1966-67 through 1975-76 has increased marginally due to renewed consumer interest in nutrition and diet. Production during this period has increased from 2,055.8 million pounds (933 million kg) to 2,623.5 million pounds (1,191 million kg), an average annual growth rate of 2.7 percent.

In California-Arizona, a Federal Order covers grapefruit grown in Arizona and the desert areas of southeastern California only. The F.O. regulates grades and sizes, but has no volume stipulation. The administration of the order is the same as that for oranges in California-Arizona.

Lemons

California-Arizona account for more than 90 percent of the lemon shipments to the fresh market. Production has increased from about 707 million pounds (320 million kg) in 1967 to 839 million pounds (318 million kg) in 1976. Per capita consumption, however, has declined from 2.3 pounds (1.04 kg) to 1.8 pounds (0.82 kg).

In California-Arizona, lemons are harvested, processed, and marketed the same way as oranges and grapefruit. Sunkist Growers provides the same services and organizational structure for all three citrus fruits.

There is a F.O. for lemons, F.O. 910, that is administered by a committee consisting of 13 members--8 growers, 4 handlers, and 1 non-industry representative selected by grower and handler members. The committee recommends weekly volumes of shipments and computes a prorate base and allotment for each shipper.

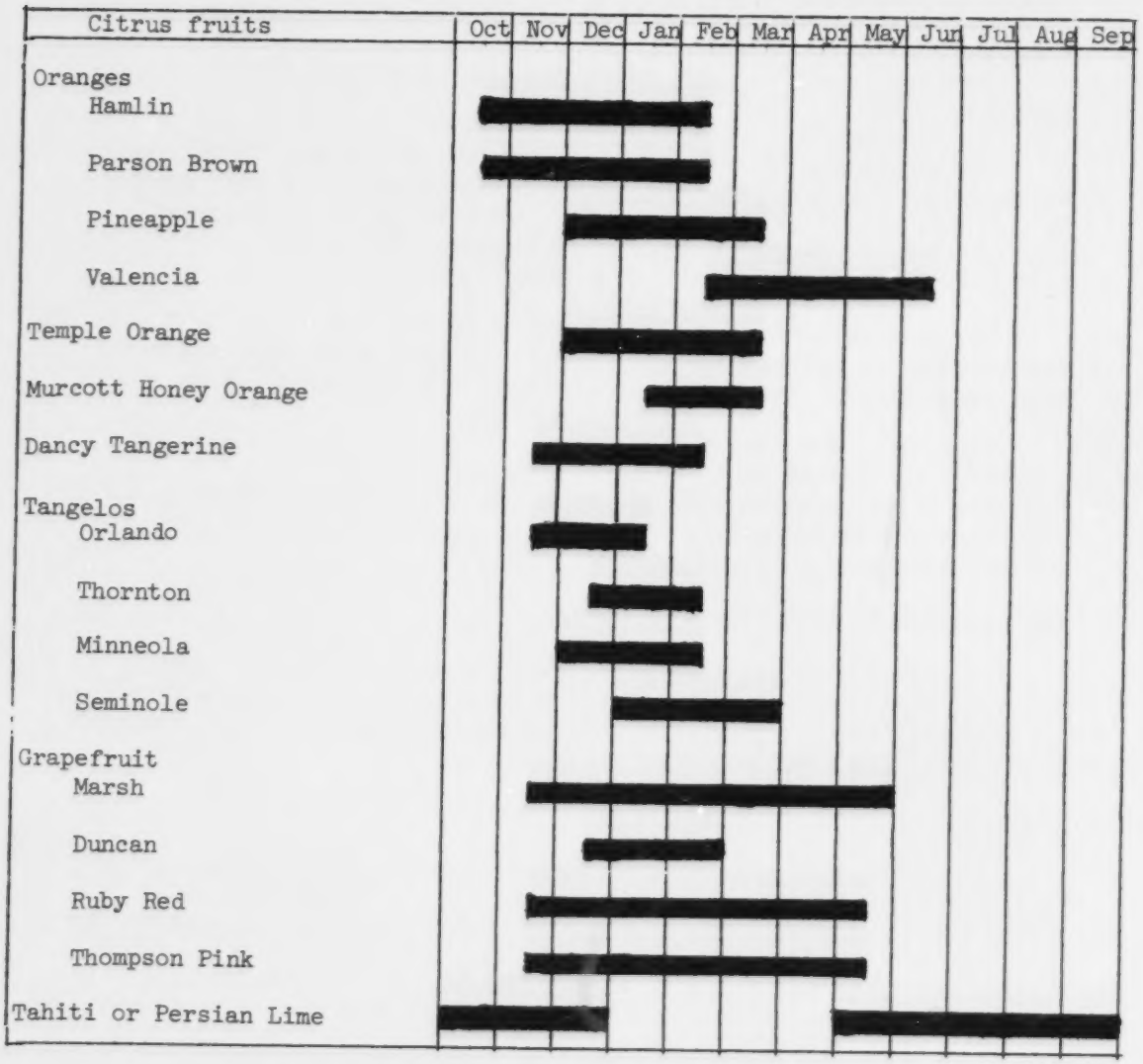
UNIT PROCESSING OPERATIONS

Proper handling of citrus fruits from the tree to the consumer involves many operations that are continually changing. Manual handling is gradually being replaced by various kinds of mechanization and bulk handling of the crop.

Picking

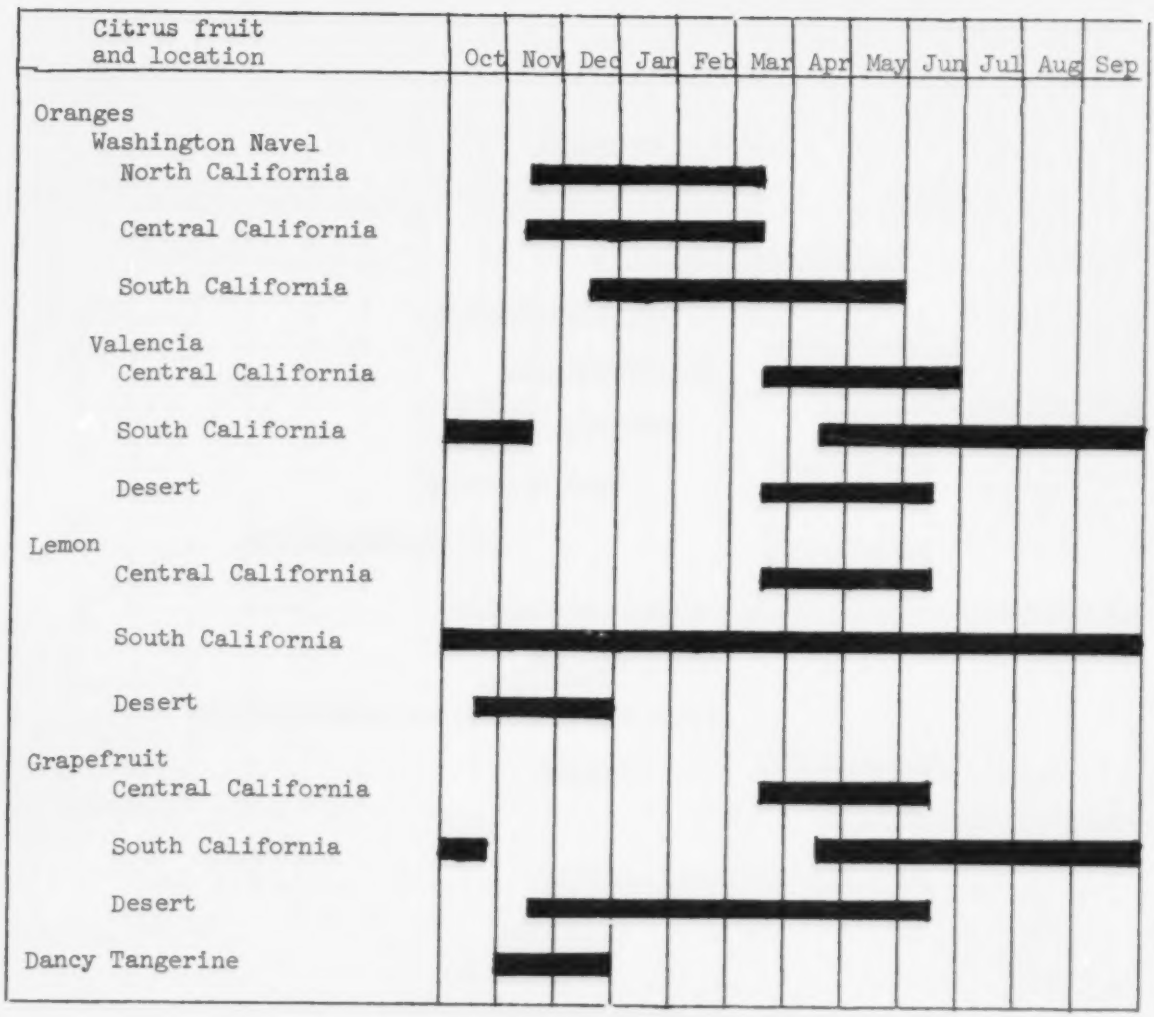
Citrus fruits are harvested in the United States throughout the year, depending on the growing area, the kind of fruit, and their respective varieties. The approximate commercial shipping seasons for Florida, California-Arizona, and Texas citrus fruits are illustrated in Figures 4, 5, and 6, respectively (Ashrae, 1971). The picking operations are conducted by trained crews from independent packing-houses or large associations. These organizations are more cognizant of market conditions than the individual growers and can schedule picking to meet market demands. The fruit not handled through cooperatives is normally sold on the tree to the shippers or processors and is picked at the latter's discretion.

The fruit is carefully removed from the trees by special clippers or by pulling and it is placed in picking bags that are emptied into field boxes. An increasing amount of fruit is handled in bulk, and the pickers put the fruit into pallet boxes or wheeled carts. In some cases, especially for processing, the fruit is loaded loose into open truck trailers. More than half of the entire Florida crop is processed.



SOURCE: ASHRAE Guide and Data Book Applications
(Am.Soc. Heating, Refrigerating, and Air
Conditioning Engineers, New York, N.Y. 1971

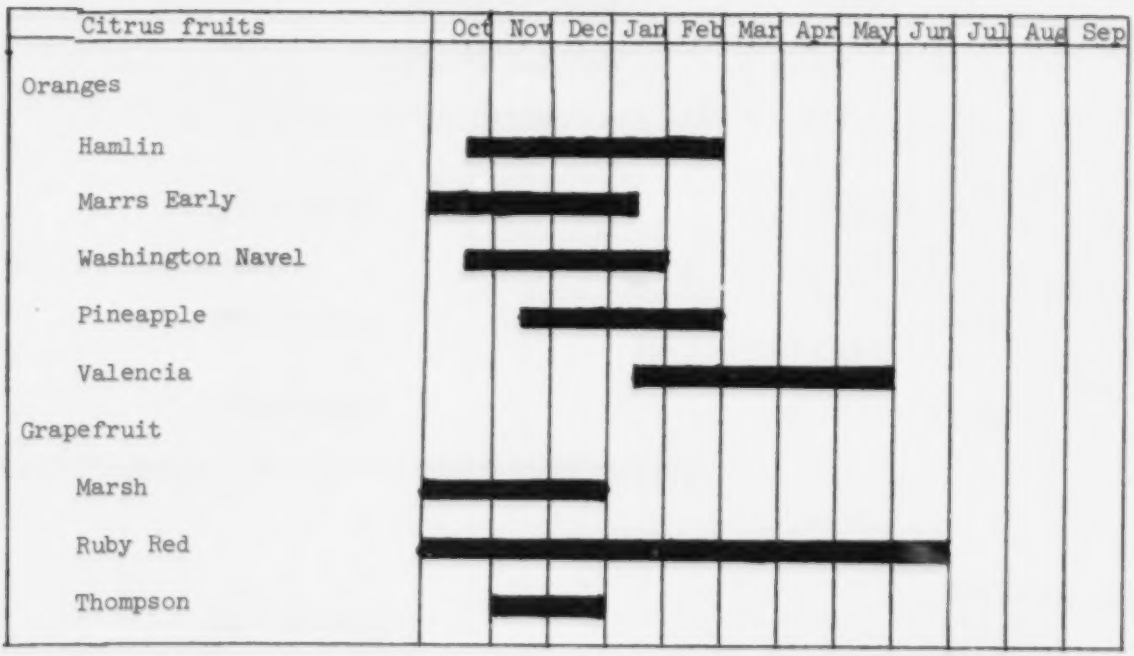
Figure 4. Approximate commercial shipping seasons for Florida citrus fruits.



SOURCE: ASHRAE Guide and Data Book Applications

(Am.Soc. Heating, Refrigerating, and Air Conditioning Engineers, New York, N.Y. 1971.)

Figure 5. Approximate commercial shipping seasons for California and Arizona citrus fruits.



SOURCE: ASHRAE Guide and Data Book Applications (Am.Soc. Heating, Refrigerating, and Air Conditioning Engineers, New York, N,Y, 1971)

Figure 6. Approximate commercial shipping seasons for Texas citrus fruit.

At the beginning of the season, the fruit is often spot-picked in order that only the riper, outside, or larger fruit is harvested. Later on, the trees are picked clean. In California, lemons are usually picked for size with the aid of sizing rings.

Picking is expensive, time-consuming, and laborious, and considerable research is being conducted to reduce the labor in harvesting. Various devices being tested include mechanical platforms and positioners, tree shakers with catch frames, and air blasts for removal of fruit. Mechanical harvesting, however, is still far from a commercial reality, and very little mechanically harvested fruit is expected to be used for fresh market because of surface blemishes that occur during the operation.

Handling

In the packing-house, citrus fruits are prepared for shipment by a number of carefully directed operations that are varied to suit the variety or quality of the fruit and the market requirements. The general aim is to keep physiological breakdown and decay to the minimum and to prepare the fruit in an attractive manner.

After the fruit is received at the packing-house, it is removed from the boxes or bulk containers by careful dumping to prevent damages to the fruit. It is then presized to remove the fruit that is too large or too small. Washing may be preceded by floating the fruit through a soak tank, which usually contains a detergent for cleaning and sometimes an antiseptic for decay control. The washer is generally equipped with transverse brushes that revolve up to 200 rpm. If not applied at the soak tank, soap or antiseptic may be dribbled or foamed on the first series of brushes. The fruit is then rinsed by a fresh water spray.

The fruit is dried mechanically by passing under fans that circulate warm air through the moving fruit. When dried, the fruit is polished and waxed, and then passed over roller conveyor grading tables. After grading, it is conveyed to sizing equipment that separates the fruit into the standard sizes being packed and drops them at stations for hand packing, or conveys them to automatic or semiautomatic box-filling or bagging machines.

The packing-house handling of California lemons for fresh market is interrupted by an extended storage period. After washing, the fruit is conveyed to a sorting table for color separation by electronic means or by human eye. Usually four colors are recognized; these are designated as dark green, light green, silver, and yellow. The dark green is a full green; the light green, a partially colored green (a green with color well broken); the silver, fully colored with a green tip (sylar end); the yellow, fully colored and mature with no green showing. Dark green fruit has a normal storage life of from 4 to 6 months; and yellow, 3 to 4 weeks. These periods are approximate, as the keeping quality of fruit varies considerably with season and grove. A light concentration of water wax emulsion is usually applied to lemons before they are put into storage.

After storage, lemons are waxed, and then sized and packed. Post-storage washing to remove mold soilage is desirable but is not recommended unless a washer incorporating very soft roller brushes is used.

Shipping and storage containers vary considerably for the various types of citrus. Fiberboard cartons have become the standard for use in California. A substantial part of California and Arizona oranges and grapefruits that arrive at eastern market in bulk cartons go to repackers for distribution in 5- or 8-pound (2.25 or 3.6 kg) polyethylene bags. In Florida, the 4/5-bushel fiberboard carton and 4/5-bushel wirebound crate have replaced the larger containers previously used. In addition, more than 15 percent of the Florida fresh fruit is consumer-packed in mesh and polyethylene bags that are shipped loose or in 40-pound master cartons. After the packages are filled and closed, they are conveyed to precooling rooms to await shipment, or directly to standard refrigerator cars or trucks. The containers are stacked so that air distribution is uniform throughout the load.

Accelerated Coloring or Sweating

All varieties of citrus fruit must be mature before they are picked. Color is not always a criterion of maturity. The natural change of color in oranges from dark green to deep orange is a gradual process while the fruit remains on the tree, the fruit remaining dark green from its formation to the time it is nearly full size and approaching maturity, when a stage is reached where the color changes may become very rapid. The color change is influenced greatly by temperature variations. A few cold nights followed by warm days may be sufficient to completely color oranges that were previously very green. The color changes in lemons and grapefruit are similar, except that the final color is yellow. Unfavorable weather conditions may delay coloring even after maturity.

Up to a certain point, the natural color changes in Valencia oranges follow the trend described, but complete or nearly complete orange color generally develops some time before the fruit is mature. Some regreening of Valencias may occur after the fruit has reached its prime. Navel oranges in California, as well as the Florida varieties of Hamlin, Parson Brown, and Pineapple harvested in late fall and early winter, may be mature and of good eating quality although the rind is green in color. Grapefruit, lemons, tangerines, tangelos, and other specialty fruits also may be sufficiently mature for eating before they are fully colored. Since the consumer is accustomed to fruit of characteristic color, poorly colored fruit is put through a coloring or degreening process in special rooms, bulk bins, or trailer degreening equipment. These units are equipped for maintaining temperatures and humidities at desired levels. Approximately 10 ppm ethylene in the air is maintained. The concentration of ethylene and the duration of the degreening periods depend on the variety of fruit and the amount of chlorophyll to be removed. During the operation, fresh air is introduced into the room, and a relative humidity of 88 to 92 percent is

maintained. In Florida, temperatures of from 82 to 85°F (26 to 29°C) usually are used, while in California temperatures of 65 to 70°F (17 to 22°C) are used. In California, the process is called sweating instead of coloring or degreening.

Oranges, grapefruit, and specialty citrus fruits that require ethylene treatment are frequently degreened as soon as they are delivered to the packing-house. Lemons in California and all citrus fruits in some packing-houses in Florida are washed and graded or color separated before being degreened.

A high percentage of Florida's early and midseason varieties of oranges receive color-added treatment. The treatment, which is done with a certified food dye, causes the rind of pale fruit to take on a brighter and more uniform orange color and is usually performed in addition to that of degreening with ethylene gas. In this process the fruit is subjected for 2 or 3 minutes to the dye solution, which is maintained at about 120°F. The color-added treatment can be given in an immersion tank filled with vegetable dye solution, or the dye can be flooded on the fruit as it passes on a roller conveyor. The color-added tank is located after the washer and before the wax applicator. Oranges with desired color at harvest time, as well as tangerines and grapefruit, are bypassed around the dye tank, or the flow of dye may be cut off as the fruit passes over the equipment. Standards for maturity are slightly higher in Florida for oranges given the color-added treatment. California oranges are not artificially colored.

Precooling

Precooling is usually accomplished by use of refrigerated air in specially designed precooling rooms after the fruit is packed. It may also be accomplished in the refrigerator car after it has been loaded.

Hydrocooling is used in a number of Florida packing-houses. The fruit is cooled by passage through a flood-type hydrocooler on a screen conveyor or in pallet boxes. Oranges are usually cooled for 20 minutes with 32°F water. The pulp temperatures are reduced 20 to 25 degrees during the process. After cooling, the fruit is packed in perforated polyethene bags or fiberboard cartons and loaded directly into precooled rail cars or trailers. Refrigerated storage rooms are provided for temporary holding of surplus fruit.

Because the fruit is moist after packing, an antiseptic, usually 0.1 percent sodium-o-phenylphenate (SOPP), is maintained in the hydrocooling water to prevent mold. Decay control is obtained sometimes by treating fruit, before packing, with a dip of 2 percent SOPP plus 1 percent hexamine. Hydrocooled citrus should be refrigerated until consumed.

In California, air precooling is used for oranges but not for lemons or grapefruit, while in Florida precooling is common practice

for most citrus fruits, particularly such specialty fruits as Temple oranges, tangerines, and tangelos.

Storage

Citrus fruits often carry incipient fungus infections when harvested. Three chemicals are approved by the Food and Drug Administration for postharvest use on citrus. Thiabendazole (TBZ) is the most effective and can be applied as a flood or spray after washing and before drying and waxing, or may be incorporated in a water wash. For protection during degreening, the fruit may be drenched with TBZ prior to its entering the coloring room. Orthophenylphenol (or its sodium salt, SOPP) is used alone or in combination with hexamine in the soak tank, in the hydrocool water, or is applied on the brushes before rinsing. It may also be incorporated in the wax coating. Biphenyl, a volatile fungistat, is impregnated in paper wrappers, box liners, and cartons. It evaporates slowly and inhibits the growth of decay organisms in transit and storage. It may also be applied in the wax. Under certain conditions it is beneficial to use a combination of these treatments since all three chemicals are not equally effective against the same decay organisms.

Citrus fruits, with the exception of lemons, are not generally stored to the same extent as some deciduous fruits, due in part to the great number of varieties that are marketed successively over a long shipping season. The difference in ripening times of the same varieties in different production areas also extends the availability of freshly harvested fruit. However, storage is needed and used to provide for orderly marketing of all varieties and for the extension of the marketing period for certain fruits. Each type or kind of citrus has specific environmental requirements; therefore, mixed storage of various citrus fruits should be avoided.

Florida and Texas-grown Valencia oranges can be stored successfully for 8 to 12 weeks at 32 to 34°F (0 to 1°C) with a relative humidity of 85 to 90 percent. The same requirements apply to Pope's Summer orange, a late maturing Valencia-type orange. A temperature range of 40 to 44°F (5 to 7°C) for 4 to 6 weeks is suggested for California oranges. March-harvested, Arizona Valencias store best at 48°F (9°C), but June-harvested fruit stores best at 38°F (3°C).

Oranges lose moisture rapidly, so high humidity should be maintained in the storage rooms. For storage longer than the usual transit and distribution periods, 85 to 90 percent relative humidity is recommended.

Florida and Texas oranges are particularly susceptible to stem-end rots. Citrus fruits from all producing areas are subject to blue and green mold rot. These decays develop in the packing-house, in transit, in storage, and in the market, but can be greatly reduced if fruit is properly treated. Proper temperature is also a very effective method for reducing decay. However, once storage fruit is removed to room temperature, decay will develop rapidly.

Storage of oranges is often complicated by the fact that prolonged holding at relatively low temperatures may induce the development of physiological rind disorders not ordinarily encountered at room temperature. Aging, pitting, and watery breakdown are the most prevalent rind disorders induced by low storage temperature. Generally, California and Arizona oranges are more susceptible to low temperature rind disorders than Florida oranges.

There appear to be no short cuts for successful long storage of oranges. Harvest at the proper maturity, careful handling of fruit, good packing-house methods, fungicidal treatments, and prompt storage after harvest are conducive to long storage life.

Florida and Texas grapefruit is frequently placed in storage for 4 to 6 weeks without serious loss from decay and rind breakdown. The recommended temperature is 50°F (10°C). A temperature range of 58 to 60°F (14 to 15°C) is recommended for the storage of California and Arizona grapefruit. A relative humidity of 85 to 90 percent is usually recommended for the storage rooms in which grapefruit is held. Loss of weight and loss of water occur rapidly and can be avoided by maintaining the correct humidity and the additional precaution of a light coating of wax.

Decay and rind breakdown are deterrents to long storage of grapefruit and may develop in fruit during storage or following removal from storage. Proper prestorage treatments with fungicides, as discussed in the previous section on disorders and storage temperatures, will greatly reduce these problems. Also, periodic inspections of the stored fruit should be made in order to terminate the storage at the very first symptoms of development of rind pitting or excessive decay.

Extensive studies have been conducted on simulated and accompanied overseas shipments of Florida grapefruit. Export may require 10 days to 4 weeks of storage in a refrigerated hold and present problems similar to those encountered in refrigerated storage. These tests revealed that Marsh Seedless and Ruby Red grapefruit picked before January retained appearance best when stored at 60°F (16°C). With riper fruit, 50 to 55°F (10 to 13°C) is a better storage temperature range for export shipments. Very ripe fruit harvested in April and May, however, develop excessive decay following storage at 50 to 60°F (10 to 16°C).

A large portion of the lemon crop is picked during the period of least consumption and must be stored until consumer demand justifies shipment. It is customary for most of this storage to be done near the producing areas rather than at the consuming areas. All lemons except the relatively small percentage that are ripe when harvested must be conditioned or cured, as well as degreened, before they are shipped. When market conditions require that the lemons be stored prior to shipment, the curing and degreening processes proceed during storage.

These lemons are usually stored at 58 to 60°F (14 to 15°C) and 86 to 88 percent relative humidity. Local conditions may require slight modifications of these conditions.

Lemons picked green but intended for immediate marketing, such as most lemons grown in the desert portions of Arizona and California, are degreened and cured at 72 to 78°F (22 to 26°C) and 88 to 90 percent relative humidity. This may take from 6 to 10 days depending on color when picked and on the nature of the lemons. The thin-skinned Pryor strain of Lisbon lemons degreens in about 6 days, whereas the thick-skinned old-line Lisbon fruit requires as long as 10 days.

Lemon storage rooms must have accurately controlled temperature and relative humidity; the air should be clean and should be circulated uniformly to all parts of the room. Ventilation should be sufficient to remove harmful metabolic products. Air-conditioning equipment is necessary to provide satisfactory storage conditions, as natural atmospheric conditions are not suitable for the necessary length of time. A uniform storage temperature of 58 to 60°F (14 to 15°C) is important. Fluctuating or low temperatures cause lemons to develop an undesirable high color or bronzing of the rind. Temperatures of 52°F and lower cause a staining or darkening of the membranes dividing the pulp segments and may affect the flavor. Temperatures about 60°F (15°C) shorten the storage life and are more favorable to the growth of decay-producing organisms.

A relative humidity of 86 to 88 percent is generally considered satisfactory for lemon storage, although a slightly lower humidity may be desirable in some locations. Higher humidities prevent proper curing of the lemons, encourage mold growth on walls and container, and decay of the fruit, whereas much lower humidities cause excessive shrinkage.

Proper stacking of the fruit containers in storage rooms is important to secure uniform air circulation and temperature control. The stacks should be at least 2 inches (5 cm) apart and the rows 4 inches (10 cm); trucking aisles at least 6 feet (1.82 m) wide should be provided at intervals.

Lemons to be stored should be treated with 200 ppm 2,4-D after they are washed. Lemons that are not washed are sprayed with a solution of 2,4-D just before they are boxed for storage. Coverage is improved by adding a few ppm of a wetting agent. This treatment aids in development of Alternaria rot, and promotes retention of healthy green buttons.

Unit operations in the citrus industry and their contribution to pollution are summarized in Table 11.

Utilities needed by fresh citrus fruit processors are electricity, water, gas, and refrigeration. Water is used in fresh citrus handling in the washing and rinsing operation, and for the removal of storage wax on lemons. The hydrocooling method is sometimes used for

TABLE 11. CONTRIBUTION OF CITRUS INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Orange and grapefruit		
Shipping field box to packing house		
Dumping to tank	X	
Washing	X	X
Rinse	X	
Inspection		X
Drying		
Surface coating, coloring	X	
Grading		
Sizing		
Stamping		
Packaging		
Precooling	X	
Cold storage		
Shipping		
Lemon		
Shipping to packing house		
Washing	X	
Sorting-color grading		X
Storage wax application	X	
Storage (ethylene treatment)		
Washing (to remove storage wax)	X	
Drying		
Grading, sizing		
Stamping		
Packing (by count)		
Shipping		

Source:

precooling. In the washing water SOPP (sodium phenylphenate) and in the lemon process for wax removal (shellac, and fungicide), foaming detergents and decay controlling fungicides are usually added. Sunkist Growers Inc. reported the following typical water usages in their citrus packing operations:

> Naval oranges. Packing 1,200 field boxes/hour, (50-55 lb each; 22.7-25.0 kg) yielding 1,200 cartons (36-38 lb each; 16.4-17.2 kg). Washing requires 350-450 gal/hr (1,300-1,670 liters) of water and rinsing requires about 500-600 gal/hr (1,890-2,270 liters). For Valencia oranges (smaller size), the same volume of water is needed for an hourly run of 1,000-1,100 field boxes.

Lemons. Washing requires 350-500 gal/hr (1,300-1,840 liters) for 1,000-1,200 field boxes. Rinsing to remove foam will require the same amount of water for 1,000 field boxes per hour. Wetting spray is used before the application of storage wax at a rate of 90 gal/hr (340 liters). A safety rinse of fresh water is used (5" spray) when the line stops using 20 gallons (76 liters)/hr. Final rinsing uses 125 gallons (472.5 liters)/hr.

Water used in these packing plants is not recycled, except 50 percent of the water is recycled from the after-storage wash water.

In October 1977, COD* from Sunkist orange processing plant effluent varied from 3,420 to 3,760 ppm; the 24-hour effluent composition from the lemon plant contained 155 ppm COD.

*Chemical oxygen demand.

SECTION 10

CELERY

GENERAL INDUSTRY CHARACTERISTICS

The celery industry is geographically dispersed throughout California, Florida, Michigan, New York, Ohio, and Washington. Concentration of production, however, is in California, which accounts for approximately 66 percent of total U.S. production, and in Florida, which accounts for approximately 25 percent. In California the major producing areas are Ventura and Monterey counties, whereas in Florida they are Palm Beach, Seminole, and Sarasota counties.

Per capita consumption of celery has remained relatively stable at 1.0 pound (0.45 kg) during the period 1967 through 1976. Production during this period has increased from 14.5 million hundredweights to 16.9 million hundredweights, an average annual growth rate of 1.7 percent. During this period, California's share of total production has increased from 57 percent to 66 percent while Florida's has declined from 32 percent to 25 percent.

This industry is seasonal in all states except California. Planting and harvesting dates are shown in Table 12.

TABLE 12. PLANTING AND HARVESTING DATES FOR CELERY

State	Planting dates	Harvesting dates		
		Begins	Most active	Ends
California				
Winter	Aug - Nov	Nov 1	Jan - Mar	Mar 31
Spring	Nov - Apr	Apr 1	Apr 1 - Jun 15	Jul 15
Early summer	Mar - May	May 20	Jun 15 - Aug 15	Aug 31
Late fall	May - Aug	Sep 1	Oct 1 - Dec 31	Mar 10
Florida				
Winter	Aug 1 - Dec 31	Nov 1	Dec 15 - Mar 31	Mar 31
Spring	Jan 1 - Apr 15	Apr 1	Apr 1 - May 31	Jul 10
Michigan	Apr 15 - Jul 31	Jun 15	Jul 10 - Nov 1	Nov 15
New York	Apr 10 - Jul 20	Jul 10	Jul 20 - Oct 25	Nov 15
Ohio	Mar 25 - Jul 15	Jun 15	Jul 1 - Oct 31	Nov 15
Washington	Apr 1 - Jul 15	Jun 10	Jul 1 - Oct 31	Nov 15

Source: SRI

UNIT PROCESSING OPERATIONS

The industry is dependent on unskilled labor for harvesting in both California and Florida, although mechanical harvesting has been introduced. Several methods of harvesting are used in this industry. In California, celery is primarily hand-harvested and packed naked in the field or in wire bound boxes, or sleave wrapped. Prior to sale in some areas, the crop is also mechanically harvested, then transported to a central packing shed where it is prepared for sale. Most of the crop that is mechanically harvested moves into the food processing sector of the food industry.

After preparation for sale, the produce is stored in vacuum coolers where buyers select lots.

In Florida, celery production is concentrated in fewer than 12 growers. Acreage and marketing are tightly controlled by a grower marketing organization. The industry is characterized by large capital investment in specialized equipment for harvesting and preparation for shipment. Mechanical and hand harvesting are commonly used on this crop, as are central packinghouses and in-field mobile packinghouses or "mule trains." In Florida, at least, celery is also an important crop for mixed vegetable shipments to end users and the industry operates under a formal involuntary marketing program through the Florida Celery Exchange.

Celery may be harvested as soon as it attains proper size. The celery plants are cut off below the surface of the ground with a sharp knife, or with a spade. The trimmers follow the cutters, lifting off the stalk and stripping off the outer leaves.

In the major celery growing areas of Florida and California, the harvest is at least partially mechanized. The crop is cut from the root and topped by a one-row harvester, which then elevates the stalks into a truck or trailer traveling beside the harvester. The celery is then transported to a stripping unit in the field and onto a field or warehouse packing system. Most of the trimming is still a hand operation, but machines that size by weight or diameter and automatic crate or carton closing machines are widely used to replace manual operations. Mobile field packing machines are also used to some extent. This involves manual cutting and placement on extension conveyors, which move the stalks to a washing unit and then to trimmers and packers on the moving unit.

After harvesting and stripping, celery is washed with fresh or chlorinated water to remove soil and trash. Washing may be done in the field when the celery is packed, but in large operations it is done in packing sheds, where the celery is inspected for grade.

Various types of crates are used in different areas. The 16-inch (40 cm) standard crate containing 30 to 36 stalks and weighing 55 to

60 pounds (25-27.2 kg) is the most common. It is sold at retail largely from bulk displays. A limited quantity of celery is prepackaged at origin in shrink-film sleeves or in open-top plastic bags. These provide protection from moisture loss and abrasion injury and permit brand identification.

Packed crates of celery are sprayed with water at 33°F (1°C) and precooled. Celery can be precooled by refrigerated forced-air cooling, by hydrocooling, or by vacuum cooling. Hydrocooling is the most common precooling method; temperatures should be brought to as near 32°F (0°C) as possible. In practice, temperature reduction is often only to 40 to 45°F (5-8°C). Vacuum cooling is widely used for celery packed in corrugated cartons for long distance shipment.

After precooling, the crates are then passed down chutes or conveyed mechanically from the precooling room to refrigerator cars or trucks, which are usually "blower iced" in warm weather to prevent deterioration. Open ventilation is sufficient when transporting in cool weather.

Celery may be stored for 4 to 5 weeks at 32°F (0°C) and at 90 to 95 percent relative humidity. Considerable heat is given off due to respiration, and for this reason the stacks of crates should be separated to allow circulation under and over the crates and between the bottom crates and the floor. Forced-air circulation is necessary to avoid temperature differential between the top and the bottom of the room.

Unit operations and their contribution to pollution are summarized in Table 13.

Utilities needed by fresh celery processors are water and refrigeration. Water is used in the field or in central packing operation to remove soil and trash. Chlorinated water (hypochloride at 50-100 ppm concentration) is used. Some water is used to spray the packed celery, and cooling is predominantly by hydrocooling, although air and vacuum cooling are also used.

TABLE 13. CONTRIBUTION OF CELERY INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Field packing		
Trimming		X
Washing	X	
Packing		
Spraying	X	
Cooling	X	
Storing		
Shipping		

Source: SRI

SECTION 11

LETTUCE

GENERAL INDUSTRY CHARACTERISTICS

Lettuce (Lactuca sativa) is the most important salad crop. It is grown commercially in at least 20 states and produced for local market and home use in areas throughout the country. The three most commonly grown types in the United States are: (1) leaf or bunching type; (2) head lettuce, including both crisphead and butterhead varieties; and (3) Cos, or romain type.

Lettuce thrives best at a relatively cool temperature. For this reason, it is grown principally as an early spring, fall, and winter crop in the South and Southwest. It is only in the most northern states, at high altitudes in the West, and near the coast in California, Oregon, and Washington that it can be grown as a summer crop. Most of the commercial crop of head lettuce is produced in California (73 percent) and Arizona (14 percent).

Lettuce is the second most important vegetable crop behind tomatoes in California and the most important vegetable fresh crop to that state. The two major producing areas are Monterey, which produces approximately 39 percent, and the Imperial Valley, producing approximately 31 percent. Important secondary producing areas are Riverside, Fresno, Santa Barbara, and San Luis Obispo.

Per capita consumption of lettuce has increased steadily from 22.1 pounds (9.5 kg) in 1967 to 24.3 pounds (11.0 kg) in 1976. Production during this period has increased from 42.4 million hundredweight to 53.9 million hundredweight, an average annual growth rate of 1.3 percent.

This industry is seasonally oriented in all commercially producing states except California. Planting and harvesting dates for the major producing states are shown in Table 14.

UNIT PROCESSING OPERATIONS

Without exception, the industry is highly dependent on unskilled labor for harvesting in each of the producing states. Harvesting of lettuce is by hand, on a selective harvest basis. Commonly about one-third of a given crop is cut at first harvest, with two or three successive cuttings, depending on market and weather conditions.

TABLE 14. PLANTING AND HARVESTING DATES FOR LETTUCE

State	Planting dates	Harvesting dates		
		Begins	Most active	Ends
California				
Winter	Sep - Dec	Nov 15	Jan 1 - Feb 28	Apr 30
Early spring	Nov - Feb	Mar 1	Apr 15 - May 31	May 31
Summer	Mar - Jun	Jun 1	Jun 1 - Aug 1	Aug 31
Early fall	Jun - Sep 1	Sep 1	Sep 1 - Nov 15	Dec 15
Arizona				
Winter	Aug 15 - Dec 1	Nov 1	Dec 1 - Mar 31	Jun 20
Early spring	Nov 1 - Feb 15	Mar 10	Apr 15 - Apr 25	Jun 20
Late fall	Jul 20 - Sep 15	Sep 15	Oct 15 - Dec 15	Jan 25
Florida	Aug 25 - Mar 30	Oct 31	Nov 15 - May 15	Jun 25
Colorado	Mar 20 - Jul 10	Jul 1	Jul 15 - Sep 20	Oct 31
New Mexico				
Spring	Jan 1 - Jan 15	Apr 25	May 1 - May 31	Jun 5
Fall	Aug 1 - Aug 15	Oct 15	Oct 10 - Oct 31	Nov 10

Source:

Head lettuce is commonly cut at or just below the surface of the ground, and all soiled and diseased leaves are removed before packing.

Essentially all of the crop is now packed in cartons (1½ to 2½ dozen heads), usually in the field, but if a plastic film wrap is used it may be wrapped and packed in the field or shed. Wrapping of individual heads of lettuce at shipping point for marketing increased quite rapidly in the early 1960s but has leveled off in recent years. Approximately 25 percent of the crop is now individually wrapped. Wrapping of the trimmed heads is done either in the field on traveling packing units or in the packing house where somewhat more sophisticated equipment is available. Most of the wrapping is done with shrink films, which cling very tightly to the head after heating.

A considerable amount of lettuce wrapping is also done at terminal repacking facilities. The advantages of origin wrapping are labor and freight charge savings, whereas terminal trimming and packaging gives a fresher product at retail.

Oriented polystyrene has been generally favored as a shrink wrap, primarily because of its permeability for respiratory gases and water vapor.

A marked change has taken place in the methods of harvesting and packing lettuce in the large producing areas of California and Arizona.

This change was brought about by the use of the vacuum cooling process. This process eliminated the need for direct icing and made it feasible to use corrugated paperboard cartons instead of wooden crates. This also moved the site for packing from the sheds to the field. Practically all of the lettuce crop from the Salinas-California district is field-packed and vacuum cooled. The cartons are mechanically placed in the precooling chambers. As much as half a carload can be handled at one time and the temperatures at the centers of the heads can be reduced to 34°F (2°C) in less than 30 minutes. The cooled cartons are placed in precooled refrigerator cars and trucks for shipment to market.

Lettuce may be kept in cold storage at 32°F (0°C) and high relative humidity for 2 to 3 weeks after harvest. However, it is highly perishable. For minimal deterioration, lettuce must be kept at a temperature as close to its freezing point as possible without actually freezing it. Lettuce will keep about twice as long at 32°F (0°C) as at 38°F (3°C). Most lettuce is now packed in cartons and vacuum-cooled to near 33°F (1°C) soon after harvest. It should then be immediately loaded into refrigerated cars or trailers for shipment.

Russet spotting, which occasionally causes serious losses, is usually not extensive at temperatures below 35°F (1°C). Lettuce should not be stored with apples, pears, cantaloupes, or other products that give off ethylene, as this gas increases russet spotting. Hard lettuce is more susceptible to this disorder than firm lettuce. Storage or shipment in low oxygen atmosphere (1 to 8 percent) is an effective method of controlling russet spotting. An increasing quantity of lettuce is shipped in modified atmospheres to aid quality retention. Modified atmospheres are a supplement to proper transit refrigeration, but are not a substitute for refrigeration. Lettuce is not tolerant to carbon dioxide and is injured by concentrations of 4 to 5 percent or higher.

Unit operations and their contribution to pollution are summarized in Table 15.

The utility needed by fresh lettuce processors is refrigeration. Water is not used in fresh lettuce handling.

TABLE 15. CONTRIBUTION OF LETTUCE INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operation	Water	Solid
Trimming		X
Packing (wrapping)		
Vacuum cooling		
Cold storage		
Shipping		

Source: SRI

SECTION 12

MELONS

Two types of melons were considered in this study--watermelons and cantaloupes or muskmelons. The muskmelon (Cucumos melo) is frequently referred to as cantaloupe by the trade. The Southwest is particularly suited to melon culture, but favorable conditions prevail in many other sections of the country, making it possible to grow the crop for local market. The leading areas for growing cantaloupes are California, Arizona, Texas, Georgia, South Carolina, Michigan, Indiana, North Carolina, Colorado, Florida, Ohio, and Maryland. The growing areas studied were Florida for watermelons and California for cantaloupes.

FLORIDA WATERMELONS

General Industry Characteristics

Watermelons (Citrullus vulgaris) are commercially produced in 16 states of the contiguous United States: Florida accounts for approximately 38 percent of production; Texas, approximately 17 percent; Georgia, approximately 9 percent; and California, approximately 7 percent. In Florida, production as a percentage of total U.S. production has increased from less than 20 percent in 1949 to its current share. The reasons for this increase include (1) an increase in yields per acre of approximately 86 percent versus a U.S. average of 43 percent, (2) use of "new land" areas, particularly in South Florida, and (3) the ready availability of water systems for irrigation. Commercial production in that state covers a wider area and greater number of acres than any other individual vegetable crop.

Per capita consumption of watermelons in the United States has decreased from 14.2 pounds (6.45 kg) in 1967 to 13.6 pounds (6.17 kg) in 1976. During this period, production has declined from 26.9 million hundredweight to 26.2 million hundredweight, an average annual decrease of 0.3 percent.

This industry is seasonal in nature (summer/spring); planting and harvesting dates in the four major producing states are shown in Table 16.

Unit Processing Operations

The watermelon industry is very dependent on skilled and semiskilled labor for harvesting. Multiple harvests are necessary with this crop. Watermelons that have been selected as being properly mature are cut

TABLE 16. PLANTING AND HARVESTING DATES FOR WATERMELON

State	Planting dates	Usual harvesting dates		
		Begins	Most active	Ends
Florida	Nov 15 - Mar 31	Mar 20	May 1 - Jun 30	Jul 1
Texas	Jan 15 - Jun 1	May 10	Jun 1 - Aug 31	Oct 15
Georgia	Mar 1 - Apr 15	Jun 15	Jun 25 - Aug 15	Sep 15
California				
Late spring	Nov - Mar	May 25	Jun 10 - Jul 20	Jul 31
Early summer	Mar - Jun	Jun 25	Jul 1 - Aug 31	Oct 15

Source: SRI

from the vines and may be windrowed or placed directly into a field truck for hauling to a loading area of the field or to a packing shed. Here they are sorted to remove those with insect or disease damage or those bruised or broken in handling. Sizing by weight classes is done by visual inspection or in some cases by automatic sizing on a conveyor system. A few melons move to market by piggyback trailers but mostly they are transported by truck.

Southern-grown watermelons generally are shipped north. Large quantities of watermelons are shipped in refrigerated or vent-cooled trucks or railroad cars. Usually, they are shipped in bulk; more than 80 percent are moved by truck, and the remainder is shipped by rail for long distances.

Cold storage is seldom used for most kinds of melons except to avoid temporarily adverse market conditions. To avoid injury by chilling, most melons are stored at 45 to 50°F (7-10°C) with 85 to 90 percent humidity.

U.S. standards are available but are not used for grading or for shipping point inspection. Quality is determined on the basis of appearance, size, seed and flesh color, and other internal characteristics of cut samples. Cut melons account for approximately 75 percent of sales through retailers, as retailers attempt to minimize effects of over- and undermature fruit at harvest and physical damage during handling. Compositional characteristics such as moisture and sugar content are important aspects of quality but are not used as a measure or standard of quality.

CALIFORNIA CANTALOUPES

General Industry Characteristics

About 76 percent of the United States supply of cantaloupes is grown in California and Arizona. Texas production accounts for about 14 percent, with the remainder being grown in the north central and southeastern states.

Unit Processing Operations

Cantaloupes are commonly harvested from 10 to 20 times from any one field during the season. Harvesting is entirely by hand labor. The pickers must be skilled in selection of melons for harvest, as selection is based on size, ground color, and ease of separation from stem. They are usually put into bags carried on the back or side of the laborer. When 60 or 70 pounds (27 or 32 kg) of melons are in the bag, the picker carries it to the field truck or trailer for emptying.

At the packing plant, the trucks are unloaded mechanically into an accumulator bin, where the melons are sorted and graded. Most plants are highly mechanized with automatic sizing equipment that determines the size on a weight or volumetric basis. The melons are washed and hydrocooled to about 40°F (5°C). About 85 percent of the melons are packed in cartons and palletized. They are stored in cool rooms until shipped to the wholesale markets.

Harvest aids for cantaloupes are used in some of the more concentrated production areas. As the mobile field packing machine moves through the field, it can cover 10 to 20 beds by means of conveyors extending from each side of the packing unit. Pickers select mature fruits and place them in a packing area on the machine; after packing, the filled cartons or crates are loaded onto a following truck for transport to the precooling and loading shed.

Although types of containers and methods of packing vary considerably, practices have been standardized in most commercial operations of the West. Crates are primarily used for shipping long distances.

Cantaloupes harvested at the hard stage (less than full slip) can be stored about 15 days at 36 to 40°F (2-5°C). Lower temperatures may cause chilling injury. Full slip cantaloupes can be held 5 to 14 days at 32 to 35°F (1-2°C). Cantaloupes are sometimes hydrocooled or precooled with top ice before shipment. Watermelons are best stored at 40 to 50°F (5-10°C) and should keep from 2 to 3 weeks. Watermelons decay less at 32°F (0°C) than at 40°F (5°C), but they tend to become pitted and have an objectionable flavor after 1 week at 32°F (0°C).

The trend in the industry is toward integrated operations consisting of private companies that grow, pack, ship, and market their melons.

The marketing may be done by their own sales desk or through sales agents. Equally important are cooperatives owned by growers that perform the same functions as the private concerns. The trend is away from independent growers and packer-shippers.

Unit operations and their contribution to pollution are summarized in Table 17.

TABLE 17. CONTRIBUTION OF WATERMELON AND CANTALOUPE INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operation	Water	Solids
Watermelon		
Inspection		X
Sizing		
Cold storage (occasionally)		
Shipping (bulk)		
Cantaloupe		
Sorting		X
Grading, sizing		
Washing	X	
Surface coating		
Hydrocooling	X	
Packing		
Storing		
Shipping		

Source: SRI

Utilities needed by fresh melon processors are water and refrigeration. Water is used in cantaloupe handling only for washing in the field if necessary and for hydrocooling prior to shipment. Surface coating spray used for cantaloupe treatment is a 4 percent oxidized polyethylene solution.

SECTION 13

ONIONS

GENERAL INDUSTRY CHARACTERISTICS

Onions (Allium cepa) are grown in 17 states; California is the largest producer, accounting for 25 percent of the total. Texas, Oregon, New York, and Idaho combined account for 50 percent of total U.S. production. There are two seasons for onions, spring onions in Arizona, California, and Texas, and summer onions in all producing states except Arizona.

Total production of onions (excluding green onions) has increased from 1.4 million tons in 1967 to 1.8 million tons in 1976. The production data include onions produced for processing, (e.g., dehydration, frozen, canned). It is estimated that per capita consumption of onions used as fresh produce has not increased in recent years.

UNIT PROCESSING OPERATIONS

Operations performed in getting an onion crop from the field to the consumer include:

(1) The onions are undercut or hand-pulled and allowed to dry for a period of 5 to 10 days before topping.

(2) The bulbs are topped by hand or machine and placed in burlap bags for further curing in the field.

(3) The bagged onions are loaded onto trucks and hauled to a building for storage or immediate packing for the market.

These operations vary from district to district, but, in general, practices that are found most suitable for a region are followed there rather consistently. Harvesting and curing are frequently quite distinct, especially when the bulbs are cured artificially, but they may be continuous or simultaneous operations in the field.

Onions may be harvested either as green-bunch onions or as mature bulbs. An onion is suitable for green bunching from the time it has reached pencil size until it begins to bulb. Such immature onions are commonly harvested in home and market gardens. In the large onion-growing districts, the crop is harvested almost entirely at the mature stage.

Harvesting may begin when the tops start to fall over. The exact time of harvest varies with environmental conditions. In the West and South it should begin during warm weather, when approximately 25 percent of the tops are down. Under cooler weather conditions, harvesting is usually delayed until 50 percent are down. In the East it does not usually begin until most of the tops are down.

A small onion plow is frequently used to loosen the bulbs. In many soils, bulbs are easily pulled by hand. In irrigated sections water may be used to soften the ground a day or two before harvesting. The pulled onions are thrown into windrows with the bulbs being shaded by the tops to minimize sunscald.

Some fall onions are now harvested mechanically by one of several methods, including the mechanical potato harvester, a combination harvester that incorporates pinch roll equipment to remove tops, and a harvester that includes an air blast to raise the tops so that rotating knives can cut them. However, the use of mechanical harvesters and bulk bins or trucks is limited to those areas and operators who have facilities for curing the onions after removal from the field.

A period of curing usually follows the harvest. In the South and West, curing is usually accomplished in a few days, but in the North the curing period may take 3 to 4 weeks depending upon climatic conditions. In Texas, onions are often pulled, clipped, and shipped the same day. Care should be taken to avoid sunscalding caused by curing too long in direct sunlight.

Tops are usually removed after they are well dried down. The tops may be cut by hand with shears, or by a topping machine. One-half to one inch of the top is usually left on the bulbs to prevent entrance of disease organisms.

Several methods of artificial curing have been tried, but the method most commonly used for early onions involves blowing heated air (110-115°F or 43-46°C) vertically through a grill on which the onions in mesh bags have been placed. Such treatment continued for a period of 8 to 12 hours usually provides satisfactory curing for either immediate shipment to market or storage for later sale.

Some tests with onions grown in South Texas showed that direct exposure to gas-fired infrared radiation for a period of 6 minutes gave better control of neck rot in freshly harvested onions than forced-air curing. However, there has been no commercial use of the gas-fired curing system.

After the tops have been removed, the onions are cleaned and graded.

A comparatively low humidity is essential in the successful storage of dry onions. At humidities higher than those at which most other

vegetables keep best, onions are disposed to root growth and decay; at too high temperature sprouting is encouraged. Storage at 32°F (0°C) with a relative humidity of 65 to 70 percent is recommended to keep them dormant.

Onions are stored in 50-pound (22.8 kg) bags, in crates, in pallet boxes that hold about a half ton of loose onions, or in bulk bins. Bags of onions are frequently stored on pallets. Bagged onions should be stacked to allow proper air circulation. Modern air-cooled storages have forced ventilation systems. Air is introduced through floor racks beneath the bins of onions. The air can be heated if necessary. Onions in bins are stored about 10 feet (3 meters) deep. Soft onions at the bottom of the bin might be distorted in shape when stored in this manner. Onions should not be stored with other products that tend to absorb odors.

When onions are removed from storage in warm weather, they are apt to sweat because of moisture condensation. This may favor decay. Warming onions gradually should avoid this difficulty.

In the northern onion-growing states, onions of the globe type are generally held in common storage, since average winter temperatures are sufficiently low to permit common storage. They should not be held after early March unless they have been treated with maleic hydrazide in the field to reduce sprout growth.

Refrigerated storage is often used to hold onions for marketing late in the spring. Onions to be held in cold storage should be placed there immediately after curing. A temperature of 32°F (0°C) will keep onions dormant and reasonably free from decay, provided the onions are sound and well cured when stored. Sprout growth indicates too high a storage temperature, poorly cured bulbs, or immature bulbs. Root growth indicates too high a humidity.

Globe onions can be held for 6 to 8 months at 32°F (0°C). Mild, or Bermuda, types can usually be held at 32°F (0°C) for only 1 to 2 months. Onions of the Spanish type are often stored; if well matured, they can be held at 32°F (0°C), at least until January or February. In California, onions of the sweet Spanish type are held at 32°F (0°C) until April or May.

Onions are damaged by freezing, which appears as water-soaking of the scales when the onions are cut after thawing. Onions that have been slightly frozen may recover with little perceptible injury if allowed to thaw slowly and without handling.

Onion sets, the small dry onions that are used as planting stock for production of early green onions, require practically the same temperature and humidity conditions as onions, but since they are smaller in size they tend to pack more solidly. They are handled in

approximately 25-pound (11.4 kg) bags and should be stacked to allow the maximum air circulation.

Green onions (scallions) and green shallots are usually marketed promptly after harvest. They can be stored 2 to 3 weeks at 32°F (0°C) with 90 to 95 percent relative humidity. Crushed ice spread over the onions will aid in supplying moisture. Packaging in polyethylene film will also aid in preventing moisture loss.

The onion industry unit operations and their contribution to pollution are summarized in Table 18.

TABLE 18. CONTRIBUTION OF ONION INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Field drying		
Topping		X
Curing		
Cleaning, grading		X
Storage		
Packaging		
Shipping		

Source: SRI

Utilities needed by fresh onion processors are gas, electricity, and refrigeration. Water is not used in fresh onion handling.

Air pollution in the form of unpleasant odors near the curing operation is the only potential problem with this crop.

SECTION 14

POTATOES

GENERAL INDUSTRY CHARACTERISTICS

The potato (Solanum tuberosum) is by far the most important vegetable in terms of quantities produced and consumed. Potatoes are grown commercially and for home use throughout the United States and lead all vegetables in terms of acreage used and value produced. Although the importance of this basic food crop has declined over the years, it remains the principal vegetable.

In most of the 40 states where potatoes are grown, production caters to local and regional markets only. Those states where shipments move outside local and regional markets include California, Idaho, Maine, New York, and Washington. Of these, California is the largest interstate shipper of fresh potatoes, followed by Idaho.

Two varieties form the bulk of fresh potato production and shipment. These are the round white produced in California, Maine, and New York, and the russet in Idaho and Washington.

Potatoes of the early crop seldom reach full maturity, on account of dry warm weather, early blight, tip-burn, and other conditions that interfere with normal growth. Consequently, the plants usually begin to die down before the crop is mature, even though good culture has been given and a spray schedule has been followed. As this stage approaches, harvesting must be initiated.

Although the harvesting time for late potatoes is determined primarily by maturity of the crop, other considerations such as market prospects, availability of help, and weather conditions may be influencing factors. The vines should mature and die before harvest so the skins of the tubers will set and thus decrease the likelihood of skinning and bruising. When necessary, the vines are killed by applying dinitro compound and ammonium sulfate spray.

Commercial application of mechanized potato harvest began about 1950. Today harvest is almost completely mechanized in all of the major producing areas.

The industry is seasonal in nature with most producing areas oriented to fall harvesting. Planting and harvesting dates for the major producing states for fresh potatoes are given in Table 19.

TABLE 19. PLANTING AND HARVESTING DATES FOR POTATOES

State	Planting date	Usual harvesting date		
		Begins	Most active	Ends
California				
Winter	Jun - Sep	Nov 20	Dec 1 - Mar 31	Apr 20
Late spring	Nov - Mar	Apr 15	May 1 - Jul 31	Aug 15
Early summer	Feb - Apr	Jun 15	Jul 1 - Aug 15	Aug 25
Late summer	Mar - Jun	Jul 15	Aug 1 - Sep 30	Oct 15
Fall	May - Jun	Sep 10	Oct 1 - Oct 31	Mar 31
Idaho	Apr 15 - Jun 15	Sep 10	Sep and Oct	Oct 15
Maine	May 10 - Jun 15	Aug 25	Sep 15 - Oct 10	Oct 20
New York				
Upstate	Apr 25 - Jun 15	Aug 10	Sep 1 - Oct 30	Nov 15
Long Island	Mar 20 - Apr 30	Jul 10	Aug 15 - Oct 31	Nov 15
Washington	Feb 15 - May 1	Jul 10	Aug 1 - Nov 1	Nov 15

Source: SRI

Per capita consumption has declined from 62.0 pounds (28 kg) in 1967 to 56.8 pounds (25.8 kg) in 1976. During this period production has also fallen from 175.8 million hundredweight to 159.0 million hundredweight, an average annual decrease of 1.0 percent.

UNIT PROCESSING OPERATIONS

Harvesting equipment comes in one-, two-, or four-row sizes with conventional diggers, rod conveyors, dirt and vine eliminators, and cross and extension conveyors for transfer of the tubers to the accompanying bulk trucks. Most of the larger harvesters provide space on the machine for several sorters so that obvious culls, clods, and stones can be disposed of before the tubers move to the bulk hopper or dump-trucks. Some have special equipment for separation of tubers from stones and clods.

Early crop potatoes are usually not stored except during congested periods. They are most perishable and cannot be expected to keep as well or as long as late crop tubers. Refrigerated storage at 40°F (5°C) following curing period of a few days at 70°F (21°C) is recommended, or they can be stored for about 2 months at 50°F (10°C) without curing.

Late crop potatoes produced in the northern half of the United States are usually stored. The greater part of the crop is held in non-refrigerated commercial and farm storages, but some potatoes are held in refrigerated storages. Potatoes in nonrefrigerated storages usually are held in bulk bins 8 to 20 feet (2.4 to 6.1 meters) deep. Shallower

bins are used in the milder climates. Some potatoes are stored in pallet boxes. In refrigerated warehouses, potatoes can be stored in sacks, pallet boxes, or bulk.

Late crop potatoes should be cured immediately after harvest by holding them at 45 to 60°F (7 to 16°C) and 90 to 95 percent relative humidity for about 10 to 14 days. This will permit tuberization and wound periderm formation (healing of cuts and bruises). If properly cured, they should keep in sound dormant condition at 38 to 40°F (4 to 5°C) with 90 percent humidity for 5 to 8 months. A temperature below this is not desirable except for seed stock for late planting. For this purpose, 38°F (4°C) is best. At 40°F (5°C) or below, Irish potatoes tend to become sweet. For ordinary table use, potatoes held at 40°F (5°C) are satisfactory but they probably would be unsatisfactory for chipping or French frying without being desugared or conditioned at about 70°F (21°C) for 1 to 3 weeks previous to use. Potatoes will remain dormant at 50°F (10°C) for 2 to 4 months. Since tubers held at this temperature are more desirable for both table use and processing than those from 40°F (5°C), it is recommended that late crop potatoes for use within 4 months be stored at 50°F (10°C) and those for later use be stored at 40°F (5°C). All potatoes should be stored in the dark to prevent greening. They should not be kept in the same room with fruits, nuts, eggs, or dairy products because of the objectionable flavor they may impart.

Minimum shrinkage and best quality potatoes result if the relative humidity is maintained near 90 percent or slightly higher. Condensation on the ceiling and resultant moisture drip is sometimes a problem when very high humidity is maintained.

Potatoes usually do not sprout until 2 to 3 months after harvest even at 50 to 60°F (10-15°C). However, after 2 to 3 months storage, sprouting can be expected in potatoes stored at temperatures above 40°F (5°C) and particularly at temperatures around 60°F (15°C). Although limited sprouting does not affect potatoes for food purposes, badly sprouted stock shrivels and is difficult to handle and market. Certain growth regulating chemicals have been approved by the U.S. Food and Drug Administration to control or reduce sprouting on potatoes. One of these, maleic hydrazide, is applied to the plants in the field 2 to 4 weeks before harvest. Another chemical extensively used is CIPC (isopropyl-N-(3-chlorophenyl)carbamate), which is applied to the potatoes after harvest, usually after a period in storage to avoid interference with wound healing. CIPC can also be applied as the potatoes are removed from storage to control sprouting during marketing.

Ventilation or air circulation in potato storage is needed to provide and maintain optimum conditions throughout the storage. In northern states, where average outdoor temperatures during storage are low, little circulation or ventilation is needed. Shell or perimeter circulation is extensively used in these areas for seed and table stock

potatoes. Forced circulation through the potatoes is required for the higher temperature storage of processing potatoes and for table and seed stock in the warmer parts of the late crop area. Rapid air circulation may lower the relative humidity of the air immediately surrounding the potatoes; it is conducive to drying and weight loss, which may be desirable if there are disease problems but undesirable with sound potatoes because of increased shrinkage.

Potatoes are usually marketed in mixed sizes with only very small and extra large tubers eliminated. Weight sizers are used sometimes, principally for long cultivars of potatoes and, particularly for count packs of baking potatoes for restaurant and institutional trade.

Until rather recently almost all potatoes were shipped to market in burlap bags holding 100 pounds (45 kg) net. The present trend is to smaller containers, which can be more easily handled during loading, unloading, and at the terminal markets. Bags holding 50 pounds (22.5 kg) are increasingly used for shipment, and cartons containing 50 pounds (22.5 kg) net are popular, particularly for the fancier pecks of sized potatoes.

Potatoes are usually prepacked for retail sale. Kraft paper bags, often filled for 5 or 10 pound (2.25-4.5 kg) weights in the back room of the grocery store, were widely used before prepacking developed. Plastic film bags are used since the knowledge of film ventilation has been developed. This provides an adequate number of holes, so that proper relative humidity can be maintained in the bags. Ventilated polyethylene bags are now widely used for 5- and 10-pound (2.25 and 4.5 kg) consumer packs. However, mesh and paper bags retain a substantial part of the prepackage business.

The 10- and 25-pound (4.5 and 11.25 kg) packs in paper or mesh are often handled and loaded individually, whereas 5- and 10-pound (2.25 and 4.5 kg) packs in polyethylene bags are usually packed in multiwall paper master containers for shipment.

Unit operations and their contribution to pollution are summarized in Table 20.

Utilities needed by fresh potato processors are water, electricity, and refrigeration. Water is used in fresh potato handling in wet dump tank and in the water flume and in occasional washing (only when the crop is very dirty). The flume water is occasionally chlorinated (80-100 ppm hypochlorite solution) and most flume water is recycled.

All fresh potato shippers in the State of Idaho water-flume their products. Average water usage for the five largest shippers in 1977 was 4.58 gallons per hundredweight (45 kg) with a range of 3 to 6 gallons per hundredweight. One smaller shipper in Idaho reported

water use at a rate of 10 gallons per hundredweight. These figures include all water used in the operation (calculated as

$$\frac{\text{water meter reading}}{\text{package weight}}).$$

TABLE 20. CONTRIBUTION OF POTATO INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Water flume	X	
Washing (occasional)	X	X
Size sorting (optional)		
Inspecting		X
Curing		
Storage		
Packaging		
Shipping		

Source: SRI

SECTION 15

SHELL EGGS

GENERAL INDUSTRY CHARACTERISTICS

The number of eggs produced for the fresh egg market and for processing has been declining. In 1967 about 70 billion eggs were produced and by 1976 production had declined to about 65 billion. Per capita consumption of in-shell eggs (fresh market) during the period declined from 285 eggs to 243 eggs. This trend, in part, is a reflection of the reduction in home baking and an increase in use of convenience foods, the increased use of egg substitutes by food processors, and the increase in consumer health concerns (e.g., cholesterol).

Eggs are produced in each of the 50 states; however, 51 percent of the eggs are produced in 8 states, with California accounting for 14 percent of production; Georgia, 9 percent; Arkansas, 6 percent; Alabama and Pennsylvania, 5 percent each; and Florida, North Carolina, and Indiana, 5 percent each.

The egg marketing industry (fresh eggs) consists of assembler-packers, of eggs who obtain their eggs from the producer and then cool, wash, disinfect, grade, pack, and market the eggs to distributors, retailers, institutional outlets, and the egg products industry. Figure 7 shows the distribution patterns.

Although there are still large numbers of producers and assemblers, the industry has slowed down in growth. Large producers and assemblers, and many vertically integrated companies or cooperatives, are beginning to dominate the market.

The production of eggs has become highly specialized, and the trend is toward large-scale egg production farms, many of which have more than 20,000 birds. Farms with over 100,000 laying hens are not uncommon in any of the major producing states. Because eggs are the major source of income on such farms, emphasis is given to producing and marketing eggs of high quality. Seasonal peaks in production have virtually disappeared and the hatching of laying stock chicks is a year-round business. Monthly production now fluctuates less than 10 percent above or below the monthly average. Long-term cold storage of eggs has therefore virtually disappeared.

Today's commercial egg industry in the United States is dominated by the Single Comb White Leghorn. This breed has found favor because of

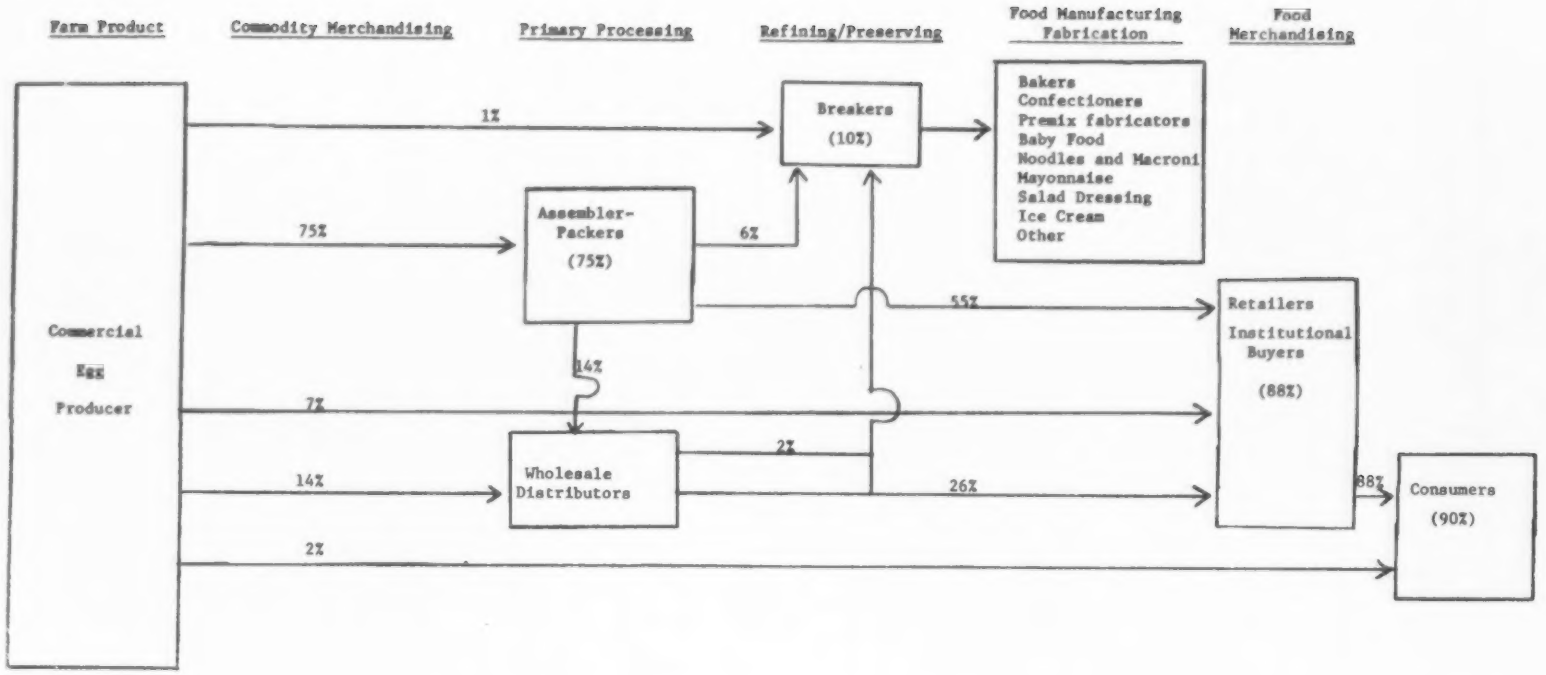


Figure 7. Egg marketing channels.

its high rate of lay, early maturity, good feeding efficiency, relatively small body size, and adaptability to diverse climates. Furthermore, leghorns lay eggs with white shell, the most widely demanded shell color among consumers.

Day length influences the rate of egg production. Diminishing day length retards sexual maturity in young pullets, and increasing length of day tends to stimulate egg production in layers. This physiological phenomenon is utilized by keeping the birds in light-tight lay houses, and time clocks are used to gradually lengthen the daily exposure to artificial light. A day length of 14 to 16 hours is commonly used at an intensity of 3/4 to 1 foot-candle.

UNIT PROCESSING OPERATIONS

The criteria usually used in evaluating egg quality are: appearance, odor and flavor, nutritive value, culinary value, and microbiological condition.

The quality of eggs is affected by the management of the poultry flocks (selection of birds, feeding well-balanced rations, keeping the flock disease free by good sanitation and vaccination, replacing the flock before an excessive decline in egg quality occurs) and the way the eggs are handled before they are marketed.

For market purposes, eggs should be infertile. Such eggs are produced by removing the male birds from the flock.

The problem of dirty or soiled eggs is largely one for the producer to solve. To produce clean eggs, it is desirable that the laying flock be kept confined to the house or confined until the laying has been completed for the day. Dry floor litter is used to reduce the number of dirty eggs. Chopped straw, woodshavings, oat hulls, chopped corncobs or cornstalks, and sawdust are used as litter. Nests are also maintained in sanitary conditions by using nesting materials such as shavings, rice hulls, oat hulls, and sawdust.

Some eggs will be soiled and will require cleaning even when laying houses and nests are kept clean. Dry buffing with emery paper or a similar abrasive is the best method for the smaller producer. Washing becomes necessary when eggs are so dirty that buffing results in an unattractive or damaged shell. However, washed eggs must be used immediately. Dirty eggs may be soaked in detergent solution for 3 minutes at 120°F (49°C) and then rinsed off in clean running water. Eggs must be dried immediately after the washing process.

Eggs are usually collected at least three times a day to reduce heat deterioration and soiling. A process diagram for shell eggs is shown in Figure 8. Wire baskets are used for gathering of the eggs. Cooling eggs in wire baskets is a desirable practice. As the eggs are

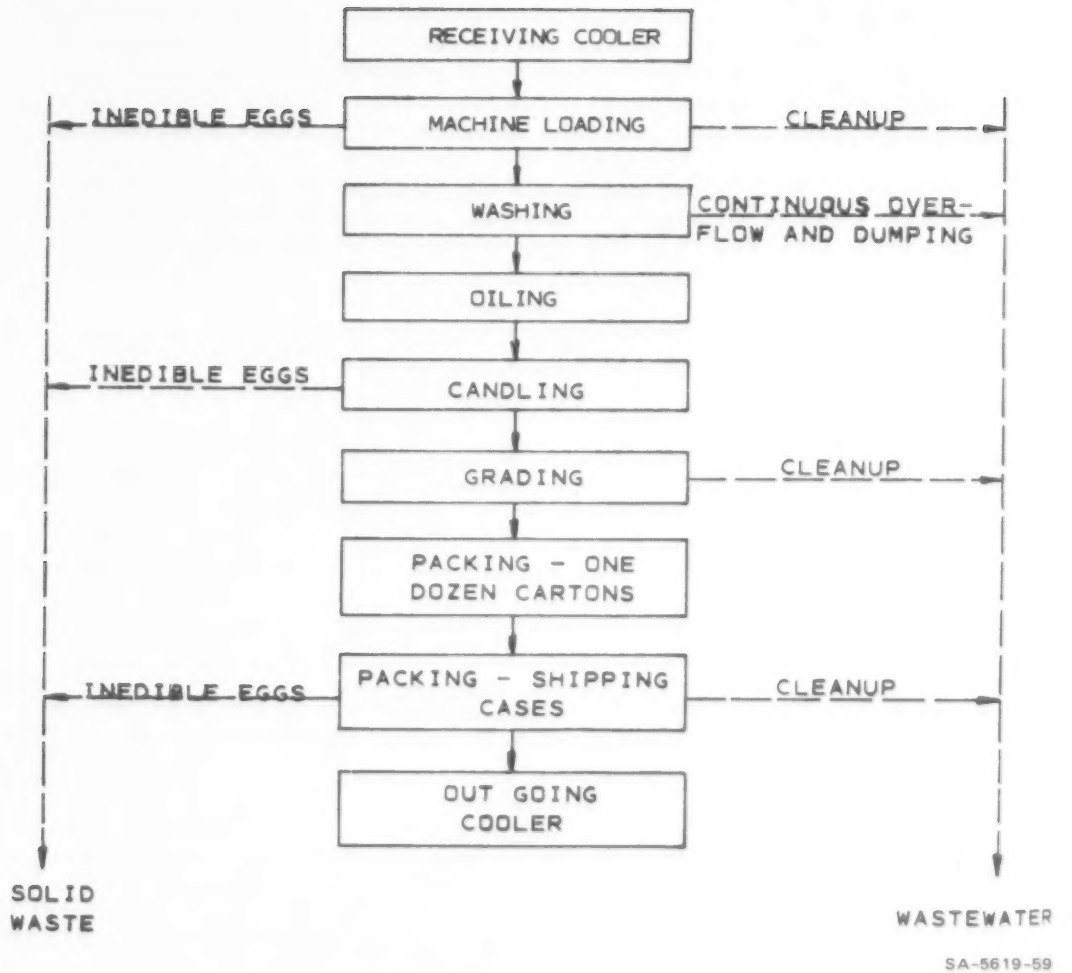


Figure 8. Shell egg process flow diagram.

gathered, they are put, basket and all, in a cool, humid place to maintain their quality and to prevent evaporation. For cooling eggs temperatures between 45 and 55°F (7 and 13°C) and 70 percent relative humidity are recommended.

Eggs are sorted for inferior quality by candling and for size by weighing. Most states have egg grading laws; some are mandatory, and others are permissive. The USDA carries out a cooperative federal-state egg grading program that provides supervision of the grading operation by federal personnel. The grading factors include quality factors (AA, A, B, C quality grades depending on quality factors of the shell, air cell, yolk, and white) and weight classification (jumbo, extra large, large, medium, small, peewee, based on ounce weight per dozen).

Mechanization is replacing hand candling, grading, and packing. Eggs are conveyed over lights for visual examination, transferred to mechanical weighing devices, and automatically packed according to quality and size.

Refrigeration is the most common means of preserving the quality in shell eggs. The use of mechanical refrigeration in the cooling and holding of eggs on the farm has become common.

Temperature and carbon dioxide play very important roles in preventing changes in the appearance of eggs during storage. The temperature should be as low as possible without freezing (29 to 30°F or -2 to 1°C) if eggs are to be kept for extended time. Temperatures this low are seldom used today because of the short marketing channels.

For short-term storage (few days), 50 to 60°F (10 to 16°C) temperature is satisfactory.

The most common container used in packaging eggs for shipment is the 30-dozen egg case. Fiber, wooden, and wire-bound cases are available in this size.

Filler flats and 2 x 6 inch cartons that hold two rows of 6 eggs each are also used. A regular filler flat for eggs is a tray having 30 individual cells arranged in five rows of 6 cells each. Normally, in regular 30-dozen egg cases, 10 regular fillers and 12 regular flats, or 30 regular 2 x 6 inch egg cartons with a flat on the top or bottom of the case are used.

A problem of increasing seriousness for poultrymen is the handling and disposal of waste materials, particularly where long-established production units have become surrounded by expanding urban housing. Poultry droppings have some fertilizer value, but costs of removal, hauling, and spreading the droppings on crop land often exceed the costs of the same nutrients supplied by commercial inorganic fertilizers. A limited amount of processing of poultry manure is being done in which

composting is accelerated, and the resulting dry, nonodorous product finds an outlet in nursery and home garden use. However, manure disposal is rapidly becoming a cost factor rather than a source of income. Where droppings are accumulated within the poultry house or on the floor for periodic removal, care must be taken to prevent fly breeding. Adequate ventilation is important to rapidly lower the moisture content of the droppings below the level at which maggots can develop. Screening of open-type houses and the inlets of environmental houses is effective. The use of chemical pesticides for fly control should be limited to emergency situations. Improper management of poultry wastes can also result in production of obnoxious odors. Ammonia fumes not only irritate workers but cause birds to be more susceptible to respiratory infections; also, eggs exposed to ammonia lose albumen quality at a more rapid rate.

The principal input materials for shell egg processing are eggs, detergent, and oil.

Unit operations and their contributions to pollution are summarized in Table 21.

TABLE 21. CONTRIBUTION OF SHELL EGG INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operation	Waste product	
	Liquid	Solid
Receiving cooler		
Machine loading	X	X
Washing	X	
Oiling		
Candling		X
Grading	X	
Packing (one dozen cartons)		
Packing (shipping cases)	X	X
Out-going cooler		

Source: SRI

Utilities needed by shell egg processors are electricity, water and steam, and refrigeration. Sources of wastewater prior to the grading of the eggs are:

(1) Cleaning of the egg handling equipment

(2) Cleaning of floors

(3) Overflow and dumping of the egg washwater.

Eggs are sometimes broken during unloading, washing, and candling. Unloading and candling equipment is normally equipped to catch these broken eggs, which then may be sold as inedibles. However, some eggs fall to the floor where they must be scraped or mopped up or hosed into a floor drain. Eggs broken during washing go into the washwater, and subsequently into the sewer. Egg washing equipment is normally of the recirculating type. The same washwater is used over and over with a small quantity of constant over-flow and make-up. This make-up comes from the water used to rinse the detergent from the washed eggs. Wastewater generated during grading and packing comes from cleaning up broken eggs and equipment cleaning. About 1 percent of the eggs crack and release organic material to the washwater. Some eggs fall to the floor where they must be scraped or mopped up or washed into a floor drain. Wastewater is also generated from the cleaning of the equipment.

Solid waste at shell egg plants is primarily inedible eggs. Eggs classed as inedibles (e.g., those with blood spots, cracks, leaks, and stains) are processed separately. Eggs that break on the floor or in grading machinery are normally recovered and also classed as inedibles. Inedible eggs are normally put in covered plastic buckets, dyed with a food color to identify them as inedible eggs, and sold to processors.

Wastewater discharged from one of the largest egg producers in the nation (Norco Ranch Inc., Riverside, California) amounts to 30,000 gallons per day (113,400 liters). Of this discharge, 2,000 gallons (7,760 liters) is highly saline waste and is treated separately from the rest; it is disposed within an inpermeable evaporator bed to prevent it from coming into contact with underlying groundwater.

The remaining waste is discharged to the city sewage system. This wash water, if sprayed onto fields, can be a source of obnoxious odor. The wastewater released from this ranch contained 8,200 mg/liter total dissolved solids, and the biochemical oxygen demand (BOD) ranged from 2,850 to 4,000 ppm.

SECTION 16

FRESH FISH

GENERAL INDUSTRY CHARACTERISTICS

The major types of fin fish and shellfish include:

(1) Groundfish (haddock, cod, whiting, flounders, and ocean perch), lobster, clams, scallops, shrimp, and sardines from New England.

(2) Menhaden, oysters, clams, scallops, striped bass, and blue crab from the Middle and South Atlantic.

(3) Shrimp, oysters, red snapper, clams, and mullet from along the Gulf Coast.

(4) Lake herring, chubs, carp, buffalofish, catfish, yellow perch, and yellow pike from the Mississippi Valley and the Great Lakes region.

(5) Tuna, halibut, salmon, groundfish, king and dungeness crab, scallops, shrimp, and oysters from the Pacific Coast and Alaska.

The number of fishermen and boats has increased from 11,082 and 6,677, respectively, in 1950, to 32,111 and 21,204 in 1969, an approximate threefold increase in each case during this period. During this same period U.S. landings have decreased from 323.4 million pounds to 267.8 million pounds, a 17.2 percent decline, whereas value of landings, including inflation, has nearly doubled from $37.4 million to $62.9 million.

The present study deals with the presentation and processing of fresh salmon, halibut, and oysters. It provides information on the care of fresh fish aboard the vessel and ashore.

HALIBUT

Pacific halibut (Hippoglossus Stenolepsis) is a large fish ranging to over 80 pounds (36.2 kg), and it is found in the cold bottom waters of the North Pacific. In accordance with regulations of the International Pacific Halibut Commission, halibut are caught only on baited long lines laid along the ocean bottom and they cannot be taken by means of a trawl. The halibut, after being caught on a long line, are brought over the rail of the fishing vessel, taken off the hook, and then placed in the

"checker" on the deck for dressing. The belly wall is slit, the viscera is removed, the gills are cut away, and the halibut, with the head and nape intact, are passed into the hold for icing.

Ice is packed in both the belly and gill cavities, after which the fish is laid on a bed of ice in the bin so that the water from the melting ice will flow around and away from the fish. It is important that the fish be laid so that any water in the belly cavity drains away from the fish and does not form a pool of blood and slime along the dorsal part of the cavity. Otherwise, halibut become sour smelling. Ample ice is placed around the halibut; this practice avoids exposure of the halibut to the air as the ice melts.

SALMON

The salmon industry is synonymous with the Pacific salmon (oncorhynchus) industry and is concentrated in Alaska, Washington, Oregon, California, and the Canadian Province of British Columbia. Pacific salmon includes five species: chinook, coho, chum, pink, and sockeye. Chinook and coho have traditionally been used in fresh and frozen forms; however, in recent years the other species have also been marketed in this form. There are generally four methods of salmon fishing: purse seine, gill net (anchor and drift), troll, and trap. Trolling is the most common method of landing salmon and is the only form of salmon fishing permitted off the Oregon, Washington, and California coastline. Gill netting is permitted on the Columbia, Puget Sound, and northward. Purse seine is widespread in Puget Sound and northward.

The method of the catch determines the initial processing. Normally, the salmon taken by seines or nets are caught fairly close to the cannery or cold storage and therefore ordinarily require no refrigeration aboard the vessel. The use of refrigerated seawater has been tried successfully for holding cannery salmon, where more than a day's delay is involved in delivery of the vessels catch to the cannery.

Seining is used extensively in both Puget Sound and Southeastern Alaska, although Alaskan regulations limit the size of the purse seine vessel to 50 feet. With both gill netting and purse seining, salmon are turned over "in the round"; that is, the cleaning is done at processing facilities onshore.

Trolling is largely a small boat operation with the exception of a few tuna vessels that participate in salmon fishing in their own off-season. Trollers commonly fish for a week to 10 days for their king and silver salmon catch, and handling and icing is an important part of their job. As the salmon are taken from the water, they are stunned by a sharp blow on the head and are lifted into the boat with a gaff hook. The salmon, soon after being caught, are bled and gutted, and the gills are removed, leaving the nape uncut just below the pectoral fins. This procedure keeps the belly walls closed during handling and icing, and

minimizes unnecessary exposure to air. A blunt implement is used to remove the kidney or blood clot, which lies below the backbone in the belly cavity. Excess blood is wiped away, and the salmon are iced similarly to halibut, using ice in the belly and gill cavities with ample ice outside and placing the salmon to allow free drainage of water, blood, and slime away from the fish.

Gill netting, restricted in Oregon and Washington to a few areas with protected waters, the Columbia and Puget Sound, has encouraged the use of small boats. The erratic nature of the seasons, and the conservation policies of Fish Commissions have also encouraged large numbers of fishermen to stay in close proximity to the permitted fishing areas.

It is important that exposure of the salmon to air be prevented by protecting them with melting ice; otherwise, yellowing of the cut belly flesh and flesh around the nape will occur. Larger king salmon (from 15 to 40 pounds or 6.8 to 9 kg) must be handled with special care to avoid breaking the flesh along the backbone and to keep the skin and scales intact. This careful handling is important if the salmon are to meet the grade standards of the high-priced mild cure salmon destined for later smoking.

A generalized marketing flow diagram for fresh salmon is given in Figure 9.

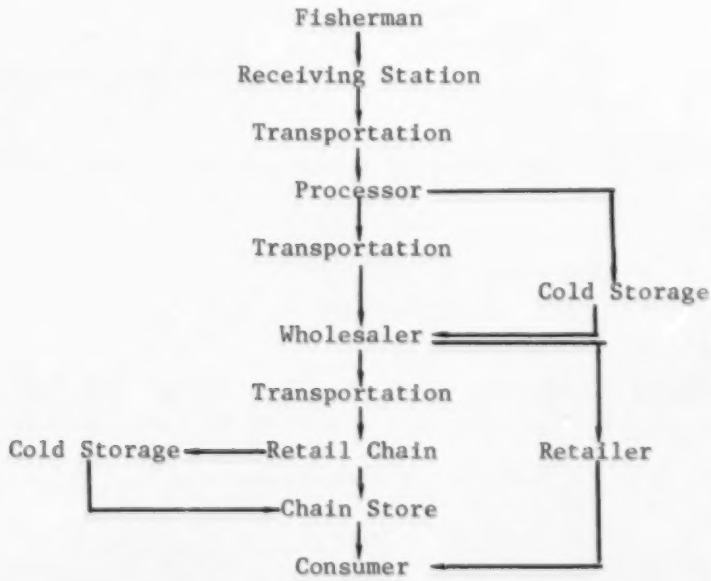


Figure 9. Marketing flow diagram for fresh salmon.

A generalized marketing flow diagram for frozen salmon is given in Figure 10.

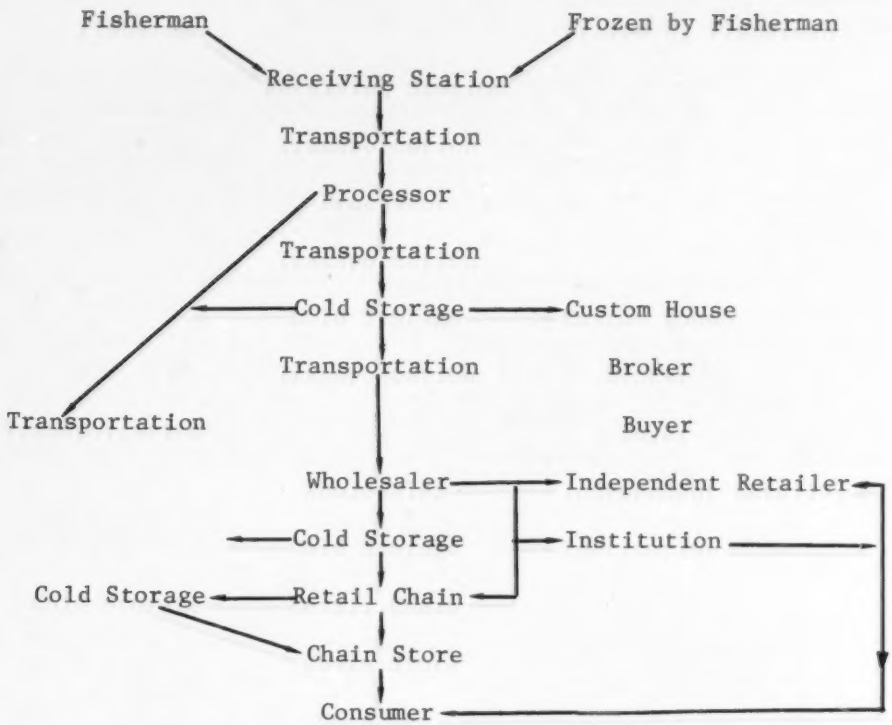


Figure 10. Marketing flow diagram for frozen salmon.

UNIT PROCESSING OPERATIONS

Quality Maintenance

After being brought to the vessel, fish must be promptly and properly cared for to assure maintenance of maximum quality.

Quality loss in fish is attributable to one or all of three principal causes:

(1) Enzymatic or autolitic action

(2) Oxidative action

(3) Bacterial action.

Reduction of storage temperature retards both bacterial or enzymatic activity. Low temperatures are particularly effective in delaying growth of the psychrophilic bacteria, which are primarily responsible for the spoilage of nonfatty fish. It has been reported that the shelf life of species such as haddock and cod is doubled for each 7 to 10°F 3-5°C) lowering of storage temperature within the range of 60 to 30°F (16 to 1°C).

Ice, to be effective, must be clean when used aboard the vessel. Bacteriological tests on ice in the hold of a fishing vessel showed bacterial counts as high as 5 billion bacteria per gram of ice. These results indicate that chlorinated or potable water should be used in making the ice at the ice plant, ice should be stored under sanitary conditions, and unused ice should be discarded from the vessel at the end of each trip.

Both flake ice and crushed block ice are used aboard fishing vessels, although flake ice is preferable because: (1) it is less expensive to produce, (2) it is easier to handle because it has less tendency to fuse, (3) the smaller, more nearly uniform size of the ice particles facilitiates mixing of ice and fish, and (4) there are fewer large pieces to cause bruising damage to the fish. New England trawlers used only crushed ice until 1967 when some vessels started using flake ice.

The amount of ice used aboard vessels varies with the particular fishery and vessel; however, it is essential to provide sufficient ice around the fish to obtain a proper cooling rate. A common ratio of ice to fish used in bulk icing on New England trawlers is 1 part ice to 3 parts fish. Recent trails made on English trawlers in boxing fish at sea with 1 part ice to 2 parts fish demonstrated improved quality in the landed fish. Mechanical refrigeration is used on some vessels to retard melting of the ice while en route to the fishing grounds; however, the hold temperature must be controlled after fish are taken to allow melting of the ice for effective cooling of the fish.

Recent findings by Portuguese, English, American, and Canadian workers indicate that a method of superchilling fish by use of ice and mechanical refrigeration can be used to extend the shelf life of fresh fish on the vessel. The fish are chilled to temperatures between 30 and 25°F. The upper temperature is the point at which fish such as cod and haddock begin to freeze; the lower temperature is the point at which the activity of spoilage bacteria is virtually stopped. In trials with cod and haddock, the shelf life of fish held at 30 to 28°F (-1 to -2°C) was from 22 to 29 days, compared to a normal shelf life of 13 days for controls in melting ice. In commercial systems used on Portuguese vessels, the fish is bulk-stowed in ice for cooling to 32°F (0°C), and is further cooled to as low as 25°F (-4°C) by refrigerated plates and pipe coils that contain cold circulating brine and are installed in the hold. Another method being studied is to ice the fish in boxes that

are spaced apart and further cooled by circulation of cold air. Currently, it appears that cooling to the lower temperature (25°F or -4°C) with the resulting partial freezing is satisfactory only for some species used in a fresh market. Fish to be filleted, such as cod and haddock, should be held at 28°F (-2°C) or above to minimize undesirable texture changes caused by partial freezing.

Salt-water Icing

The importance of maintaining iced fish storage temperatures close to the freezing point of fish has been stressed by several workers. One method of obtaining lower ice temperatures is to depress the freezing point by adding salt to the water from which the ice is made. Adequate amounts of ice made from a 3 percent solution of sodium chloride brine will maintain a storage environment of about 30°F (-1°C) for the fish. Tests conducted on the storage of haddock in salt-water ice showed that those fish were cooled faster and to a lower temperature than were fish iced in plain ice. However, the salt-water ice melted faster than the plain ice because of the lower latent heat and greater temperature differential of the salt-water ice. Therefore, once the salt-water ice melted, the fish stored in this ice rose to a higher temperature than those stored in plain ice. Since it is not always practicable to renew ice on fish at sea, sufficient quantities of salt-water ice must be used initially to make up for the faster melting rate.

In making ice from water containing a preservative, rapid freezing or the use of a stabilizing dispersant, or both, is essential to prevent migration of the additive to the center of the ice block. This problem is not encountered in flake ice because flake ice machines are designed to freeze water rapidly into thin layers of ice, thus fixing additives within the ice flakes.

Use of Preservatives for Treatment of Chilled Fish

In the United States the use of antibiotics in ice or in dips for treatment of whole or gutted fish, shucked scallops, and unpeeled shrimp was revoked, in effect, during 1967 when the Food and Drug Administration deleted the tolerances for antibiotic substances in these and other foods from the pesticides regulations. Several preservatives are acceptable and are used to some degree for extending the shelf life of fresh fish and shellfish. These include chlorine compounds, benzoates, and chemicals that inhibit the growth of spoilage bacteria on fish. Such preservatives are of most value when used on high quality fish along with good handling, sanitation, and storing procedures.

The use of refrigerated sea water (RSW) is limited in the United States and Canada for preserving fish to be canned or to be used for industrial products.

Boxing at Sea

The use of containers instead of bulk storage aboard fishing vessels offers many advantages. This procedure is known as boxing at sea and it is successfully used by European fisheries. However, it is not generally practiced in the United States because it requires additional labor for handling boxes on the vessel.

Shore Plant Procedure and Marketing

Proper use of ice and adherence to good sanitary practices are necessary to assure maintenance of iced fish freshness during unloading from the vessel, at the shore plant, during processing, and throughout the distribution chain. Fish landed in good quality will spoil rapidly if these practices are not carried out.

Fish unloaded from the vessel are usually graded by the buyer for species, size, and minimum quality specification. A price is based in part on the quality in relation to market requirements. Fish may also be inspected by local and federal regulatory agencies for wholesomeness and sanitary condition. Organoleptic criteria are most important for evaluating quality; however, there is a growing acceptance, particularly in Canada and some European countries, of objective chemical and physical tests as indexes of quality loss or spoilage.

After the fish are brought into the plant, they are beheaded, if this has not already been done at sea, and the body cavity is flushed to remove ice. The fish are graded by size and then processed whole or fletched. Wooden boxes are frequently used for transporting fish, but they are not recommended for reusable applications because they are a source of microbiological contamination. Ice should be applied generously to each box of fish, even if the period prior to holding is only a few hours.

Large boxes of resin-coated plywood, reinforced fiberglass, or plastic, which hold up to 1,000 pounds (454 kg) of fish and ice, are used by some plants in preference to icing fish overnight on the floor. These tote boxes are moved and stacked by use of a fork lift, can be used for trucking fish to other plants, and make better use of plant floor space.

Fresh fish are marketed in many different forms: fillets, whole fish, dressed-head on, dressed-headed (head removed), or in some instances as steaks. The method of preparing fish for marketing depends largely on the species of fish and on consumer preference.

Packaging

At the point of processing, most fresh fish is packaged in institutional containers of 5- to 35-pound (2.25 to 16 kg) capacity.

Steel cans, aluminum trays, plastic-coated solid fiber boxes, wax-impregnated corrugated fiberboard boxes, foamed polystyrene boxes, and polyethylene bags are used.

Fresh fish is often packaged while it still contains process heat from wash water. When this is done, it is advantageous to use a packaging material that is a good heat conductor. The fresh fish industry makes little use of controlled prechilling equipment in conjunction with packaging systems, and, as a result, product temperatures may never reach the optimum level subsequent to packaging. Traditionally, institutional fresh fish travels packed in wet ice; in this case, it may cool to the proper level in transit even if process heat is initially present. However, there is a trend toward the use of leaktight shipping containers for fresh fish, because modern transportation equipment is not designed to handle wet shipments. This requirement virtually precludes the use of wet ice in shipping containers; shippers who make use of leaktight shipping containers will have to upgrade their product temperature control systems to ensure that the fish reaches ice temperature prior to packaging. Rapid prechilling systems that result in crust freezing can be applied to some fresh seafood products, but this practice must be used with discretion since it sometimes produces deleterious effects on quality.

Some general requirements for institutional containers for products such as fillets, steaks, and shucked shellfish are: (1) the container should have sufficient rigidity to prevent pressure from being exerted on the product, even when containers are stacked or heavily covered with ice; and (2) the container should prevent ice melt-water from contacting the product. Some containers are provided with drains to permit the drip associated with the fish itself to run off. Others are sealed and may be gastight. Increased shelf life has been reported in conjunction with the use of gastight containers. One problem associated with sealed containers, however, is the accumulation of a strong odor that is emitted when the package is first opened. Although this odor may be somewhat foul, it soon dissipates and has no adverse effect upon quality. Dressed or whole fish may be placed in direct contact with ice in a gastight shipping container.

Shipping containers for fresh fish, if they are of the draining type, may be of nailed wood, wirebound wood, wax-impregnated corrugated fiberboard, or foamed polystyrene. They are usually of 100- to 200-pound (454-908 kg) capacity. Reusable shipping containers are seldom used.

Leaktight shipping containers are used with nonrefrigerated transportation systems such as air freight, and, consequently, they require insulation. Foamed polystyrene is particularly suited for this application. For typical air freight shipments, the most economical thickness of insulation is between 1 and 2 inches. To maintain product temperature in transit, shippers use either dry ice, packaged wet ice, packaged gel refrigerant, or wet ice with absorbent padding in the bottom of the container.

Foamed polystyrene containers may be of molded construction, or they may be of the composite type in which foam inserts and a plastic liner are used in conjunction with a corrugated fiberboard box.

At the retail level, fresh fish may be handled by either of two methods. Stores with service counters display their fish in unpackaged form. Many markets do not have service counters, however, so their fish must be packaged for the consumer prior to displaying for sale. Both types of outlets normally receive the product in institutional containers. If the fish is prepackaged at the market, high labor and packaging costs may be incurred; in addition, the temperature of the product is likely to rise. Often, relatively warm fish is placed in a foam tray, wrapped, and displayed in a meat case, the temperature of which may be 40°F (5°C) or more. This drastically reduces the shelf life of the fish. Centralized prepackaging at the point of initial processing appears to have many important advantages over the present system.

Storage

The maximum storage life of fish varies from species to species. In general, the storage life of East and West Coast fish properly iced and stored in refrigerated rooms (35°F or 2°C) is about 10 to 15 days, with 15 days as the maximum. This is dependent on the condition of the fish when unloaded from the boat. Generally, fresh-water fish properly iced in boxes and stored in refrigerated rooms may be held for only 7 days. Both figures are from the time the fish is landed and processed to the time of consumption.

Cold storage facilities for fresh fish should be maintained at about 35°F (2°C) and over 90 percent humidity. Air velocity should be limited to control ice loss. Temperatures less than 32°F (0°C) retard ice melting and can result in excessive fish temperatures. This is particularly important when storing round fish such as herring, which generate heat from autolytic processes.

Floors should have adequate drainage with ample slope toward drains. All the inside surfaces of the cold storage room should be of a construction that is easy to clean and must have the capacity to withstand the corrosive effects of frequent washings with antimicrobial compounds.

OYSTERS

General Industry Characteristics

The oyster industry can be arbitrarily broken down into two areas--the East and Gulf Coast, and the West Coast.

The East/Gulf Coast harvests the American or Eastern oyster; the leading producers are located in Maryland, Louisana, Virginia, and

Florida. James River in Virginia is the largest seed oyster producing area in the world and supplies over 70 percent of the oysters planted in Virginia. Connecticut estuaries are important seed producers that supply most of the seed used by Long Island oyster farms. Harvesting techniques vary with local regulations and are frequently limited to inefficient, labor intensive methods on public grounds. Private operators, on the other hand, can often use efficient escalator and hydraulic dredge boats. Additionally, private oyster farmers can harvest beds throughout the year, whereas public areas are frequently closed 4 to 5 months of the year depending on local regulations.

West Coast oyster production is centered on the large Pacific oyster, with limited production of the small Western native oyster in the Puget Sound area. West Coast production is almost entirely by aquaculture on privately leased bottoms, with Washington the major producer. Most seed oysters are still imported from Japan, a practice started in the 1920s; however, there is increasing reliance on hatching seed, and some limited natural set occurs. Harvesting techniques vary and depend largely on the bottom and tidal amplitude.

Aquaculture is important to the national production of oysters. In 1974, aquacultural activities accounted for 40 percent of the U.S. oyster harvest.

The oyster industry is one of the top five fisheries providing employment in the harvesting, processing, and distribution of seafood. In 1973 there were approximately 11,748 oyster harvesters (including part-time harvesters). The number of harvesters has been decreasing from an average of 14,000 in the 1950s and 13,700 in the 1960s.

Domestic landings of oysters have declined from 90 million pounds (meat weight) in 1929 to an average of 53.9 million pounds in the 1971-75 period. On the other hand, the value of production has been increasing. The harvest value in 1967 was $32.2 million compared to $45 million in 1975. Corrected for inflation, the on-vessel prices actually declined in the period 1968-73 and then increased by 14 percent in 1975. This trend can be compared with prices paid to fisherman for all edible fish, which has more than doubled since 1967.

Oysters are marketed mainly in fresh product form. The sale of oysters in the shell for raw consumption has significant regional importance. Almost all the oysters produced by oyster farms in Long Island are sold for the raw bar trade, and in Louisiana, private beds are harvested year around to meet the market demands in New Orleans. On the other hand, native Western and Pacific coast oysters are not normally eaten raw.

Unit Processing Operations

Oysters are delivered alive in the shell to the shore plant. They are unloaded from the boats by means of a bucket or hoist or by conveyors.

The processing of oysters consists of two basic operations--shucking and packing. Shucking of the oyster is accomplished using either manual or mechanical methods. Manual operations are more prevalent.

In mechanical operations the oysters, after arriving at the plant in wire cages, are conveyed into the plant to two sequential drum washers. The first washer cleans the oyster shells, and removes broken shell, seaweed, and other matter. Dead oysters are discarded. The second washer has a different pitch and serves to jar the valves far enough apart to allow steam to enter during the cooling. Loose empty shells are manually removed before the oysters are collected in retort baskets. The oysters are steamed in retorts under pressure and the resulting oyster juice or broth is piped to a holding tank and later condensed. After cooling the meat is separated from the shell manually or by brine flotation, or by a mechanized method using a specially designed drum washer. Both the meat and the shell are collected in a brine flotation tank when the buoyancy of the meats allow the saturated salt solution to float them to a blow tank that agitates and adds water to the product. The shells sink to the bottom of the brine tank, where a belt collects them and deposits them outside the plant. The meats go through a final drum washer before being manually inspected. The oyster meat then is fresh packed in large cans together with the condensed broth, chilled, and shipped.

In hand-shucked oyster processing, the oysters arrive at the plant by boat, barge, or truck and conveyed into the plant on a belt or in buckets. The shells are washed to remove most of the mud, and to facilitate shucking. Shuckers open the shells manually by forcing the valves apart and cutting the adduction muscle. The meat is put into buckets, washed on a skimmer table, and placed in the blow water. The blow washer typically holds about 80 gallons (300 liters) of water. For the first 5 to 15 minutes, air is bubbled through the washer; for the following 20 to 50 minutes, overflow water is added to the tanks. The oysters are dewatered on a skimmer table and then packed in cans.

Unit operations and their contribution to pollution are summarized in Table 22. Utilities needed by fresh fish processors are electricity, gas, steam, water, and refrigeration.

Devisceration of fish is generally accomplished at sea. After being washed, the fish is maintained in ice storage. Onshore, the fresh fish is packaged in institutional containers and delivered to the retail outlet in ice. The fresh fish industry comprises a large number of plants, with wastewater flows and loads of great variability. The waste loads from the halibut processing operation are relatively low. Processes having an average of 4.3 kilograms/hour production the flow rate was observed as 110 gallon/minute (6.94 liters/second) with BOD_5 content of 396 mg/liter, and 326 mg/liter TSS.

TABLE 22. CONTRIBUTION OF OYSTER INDUSTRY UNIT OPERATIONS TO POLLUTION

Unit operations	Water	Solids
Halibut, salmon		
Devisceration	X	X
Icing	X	
Preservative treatment	X	
Unloading from vessel		
Grading		X
Inspection		
Boxing (ice)		
Preparation for market (filleting, descaling)	X	X
Packaging for shipment		
Prechilling	X	
Shipping		
Storage		
Packaging for retail		
Oysters		
Delivery		
Holding bins		
Drum wash	X	X
Impact shock	X	X
Empty shell removal		X
Retort	X	
Shucking	X	
Brine flotation/grading	X	X
Blow washing	X	
Drum washing	X	
Packing		
Chilling		
Shipping		

Source: SRI

Waste loads from steamed and canned oyster processes are reported to be higher than those from the hand-shucked operations. The oyster processes mean production of 0.712 ton/hour produced 13.3 liters/second (211 gallon/minute) waste flow containing 624 mg/liter BOD_5 and 1,580 mg/liter TSS (total suspended solids).

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